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INFILTRATION OF POROUS FOODS WITH HIGH CALORIC, NON-AQUEOUS, EDIBLE MATERIALS

by

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FOREWORD

This investigation represents a facet of a broad experimental program directed to the design and development of special food packets for the combat soldier who must carry on his person his entire food supply for prolonged periods during which resupply is not feasible. Design of such food packets must assure wholesomeness and acceptability. It is essential that packets impose a minimum addition to the weight and bulk of the already immoderate load a soldier must carry.

While freeze drying permits maximum weight reduction with minimum impairment of acceptability for a wide variety of foods, it provides little or no reduction in food bulk. Two general procedures appear feasible for compensating the low bulk density resulting from the porosity of freeze dried foods. One such procedure seeks to eliminate the porous structure through compression; this alternative has been the subject of several investigations. The second procedure, which provides the basis for this investigation, seeks to fill the pores of freeze dried foods with stable, high caloric materials, which are normally consumed in conjunction with the parent food. This latter procedure appears to be potentially applicable to other porous items such as bakery products.

This report describes work conducted under contract DA19-129-AMC-84 with funds provided by the project titled, Combat Feeding Systems. The investigation was performed at the Central Engineering Laboratories of the FMC Corporation, 1185 Coleman Avenue, Santa Clara, California. Dr. R. A. Lampi served as Official Investigator. His collaborators were H. Takahashi, Jean S. Tannon, Mohamman H. Nosvati, Silvestre Sierra, and William B. Scalf.

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ABSTRACT

Methods together with suitable high caloric formulations were developed for filling the voids of representative baked items and freeze dried meats, fruits and vegetables. Panel tests for acceptability and relevant physical, chemical and microbiological observations are reported for infiltered products stored for 4 months at a maximum temperature of 38°C. Preparative experience has been extrapolated into an engineering flow diagram for large scale production of infiltered foods.

I. INTRODUCTION

Freeze-dried foods and many bakery items have low bulk densities and yield relatively few calories per unit volume. From a logistics point of view, it would be advantageous to increase caloric density of these foods by filling the voids with edible high caloric material. To explore this possibility, work was initiated under Quartermaster Corps Contract DA 19-129-ANC-84(N) to infiltrate selected dried foods with high caloric fillers to yield a caloric content of 4.4 Kg-cal per gram. Under the subject contract, two phases of work were involved.

The first phase of work dealt primarily with the development of formulae and infiltration techniques for twelve various foods. The detailed results of this experimental work were covered in Phase I, Final Report.

This report is the final report of the second phase of studies covered under the contract. The objectives of this phase were to apply the successful infiltration techniques and formulas of Phase I to fourteen specific foods and to evaluate the storage stability of these infiltrated foods by chemical, organoleptic and microbiological methods. Also included in Phase II scope of work is the preparation of a flow sheet diagram supplemented with type and capacity of unit equipment to process 500 Kilograms per hour of infiltrated foods.

This final report is divided into two separate sections:

Section I The Preparation and Evaluation of Fourteen Infiltrated Foods.

Section II Flow Sheet Diagrams and Design of Equipment for Producing 500 Kg/hr of Infiltrated Foods.

II. EXPERIMENTAL

For the most part, the infiltration techniques and formulas developed in the first phase were employed in producing the high caloric foods specified for the second phase work. Special emphasis was placed on selecting infiltration methods which could be most easily adapted to automated processing since these techniques would supply the necessary data for the design and detail of the process flow diagrams for producing the high caloric food items.

To best describe the experimental work performed, the discuscussion will be divided into three sections.

1. A description of the infiltrating techniques and methods for evaluating the infiltration.

2. The specified foods and the materials used for filler formulation.

3. The infiltration procedures and filler formulae for each of the fourteen foods.

A. Description of Infiltrating Techniques and Evaluating Infiltration

Two of the four methods of infiltration described in Phase I Final Report were used for preparing the foods for the second phase studies. A third method of impregnation was necessitated for one of the food items.

1. Infiltration Methods

a. Vacuum Release

The main method of penetration was vacuum release. The equipment set-up for this procedure involved the use of a vacuum dessicator and a vacuum pump, and this set-up is illustrated in Figure 1. Samples to be impregnated were kept submerged in the liquified lipid filler material and placed in the vacuum dessicator. A 30" Hg vacuum was drawn and released as soon as the emulsion or mixture began to bubble. For all foods infiltrated in this manner, subjecting each sample to six consecutive cycles of vacuum and release was found to produce the best results. Less than six vacuum-release cycles resulted in incomplete infiltration. More than six cycles did not result in any additional infiltration, since penetration was either near complete or further penetration was limited because of hardening of the absorbed lipid filler material within the food. This six cycle vacuum-release method was satisfactory only when using relatively low viscosity filler mixtures.

b. Positive Pressure Method

For those foods requiring a higher viscosity emulsion, positive pressure proved to be the best method for achieving infiltration. The one by two inch rectangular die shown in Figure 2 was used for the pressure method of infiltration. The emulsion was placed over the sample and placed in a Carver press. Pressure was slowly applied until reaching 100 pounds per square inch and held for one minute to permit escape of air entrapped in the food. Because pressure is

applied to the food in this method, only firm dry foods can be infiltrated successfully.

c. Manual Injection Method
For one food item, macaroni, the above mentioned methods of infiltration were not applicable and a manual injection method was necessary In this procedure, a pump was fashioned from a short piece of tubing on the stem end of a small funnel. A blunt ended 20 penny nail was used as a plunger for the pump. (This set-up is illustrated in Figure 3). A single piece of macaroni was fitted into the tubing and powdered filler material in the funnel was pushed into the void space of macaroni.

2. Evaluation of Infiltration

Two methods of evaluating the degree of infiltration were employed.

a. Visual Evaluation
The initial method of evaluating the degree of infiltration was by visual examination of the infiltrated food through a 2 1/2 power magnifying glass. When two phase (aqueous-lipid) emulsions were used for infiltration the aqueous phase was tinted with a royal blue dye (FD&C Blue No. 2). In Phase I work, this dye was found to tint only the aqueous phase, and this tinting helped in ascertaining the degree of penetration achieved by each phase.

b. Quantitative Evaluation
After visual evaluation of the infiltrated food quantitative methods were employed to determine if the infiltrated foods met the 4.4 Kilogram caloric requirements by weight and by volume. The quantative methods involved calculations of both true and apparent densities of each food before and after infiltration. The density information was then used in caloric calculations for each item. Further details of these calculations will be discussed in the section on evaluation of infiltrated foods.

Foods and Materials Used in The Infiltration Studies

1. Foods

The contract specifications called for infiltrating fourteen foods to be selected from the following items.

1. Pound Cake (or doughnuts)
2. Pancake (or waffles)
3. Zwieback toast (or crackers)
4. Puffed rice (or puffed wheat)
5. Macaroni
6. Chicken*
7. Beef*
8. Shrimp* (or fish*)
9. Peas* (or corn*)

10. Asparagus* (or green beans)
11. Strawberries* (or pineapple)
12. Apples* (or peaches*)
13. Cottage cheese* (or scrambled eggs)
14. Dehydrated Beef Stew* (or chicken with rice)

[*Freeze-dried]

The actual foods selected are listed first, with the alternates in parenthesis. The alternates are listed because, in many cases, the efforts to infiltrate these foods are discussed in the preparation of the individual foods.

2. Filler Materials

During the first phase, a wide variety of filler compositions were explored, mainly in attempts to reduce "greasiness" during consumption. Of those fillers, only the more promising ones from the aspects of completeness of impregnation or organoleptic acceptability and probability of good stability during storage were used in the second phase.

Because the infiltrated foods had to undergo storage at 100°F, only those lipids which had melting points exceeding this temperature could be employed. Acceptability of the infiltrated foods by a taste panel was an additional requirement which precluded the use of some high melting point lipids because of the totally unacceptable taste and/or mouth feel.

CCC; a shortening supplied by the Durkees Famous Foods Company, Berkely, California; was found to be acceptable in many of the filler formulae used for infiltration. The 112°F melting point of this lipid made it ideal as far as the 100°F storage requirement was concerned. In addition, this shortening mixture was found to be very stable under adverse storage conditions, and most of all, the mouth feel and taste of this lipid when used in filler combinations was found to be the most acceptable.

Myverol 18-06; supplied by the Distillation Products Industries Incorporated, Rochester, New York; was used to some extent in formulating coatings for several of the infiltrated products. Myverol, because of its high melting point of 149°F, was useful in raising the melting point of the chocolate coating used for several of the food items.

Liquicane Type 50; a high solute sugar syrup containing 50% invert and a Brix of 77° made by the California and Hawaiian (C&H) Sugar Company, Crockett, California; was successfully used as an infiltrating material for several dried foods. This syrup added the greatest amount of calories of any syrups tested and was rated most acceptable on the basis of taste.

Purity 270 Starch, produced by the National Starch and Chemical Corporation, New York, New York, used extensively in Phase I filler formulations, was again employed in the make-up of fillers of the second phase. A mixture of dry Purity 270 starch and melted CCC shortening resulted in a stable mixture which could be easily infiltrated. On rehydration, this starch combined with the water of rehydration and formed a gravy which complemented the product.

When satisfactory infiltrated products were achieved with the basic lipid, starch and syrup ingredients, attempts were made to enhance the flavor of the filler compounds with several types of flavoring materials.

Various oil soluble flavors were added to pure lipid fillers, but often proved to be unsatisfactory because it was not possible to achieve equally acceptable flavor levels in both the dry and rehydrated form of the infiltrated products. If the flavor level in the rehydrated product was acceptable, it was overpowering when the product was consumed dry. When the flavoring level was adjusted for the dry infiltrated product the flavoring went unnoticed in the hydrated product.

Less potent flavoring materials such as vanilla and other common spices were found to be useful in several filler formulations, and the use of these falvorings will be discussed under the preparations of the individual foods. For many foods, salt would have enchanced the taste of the infiltrated product, but since salt is known to have an adverse effect on lipid stability, it was not used in any filler preparation. Because the selection of suitable flavorings is a time consuming art and may add more variables as far as stability and acceptability is concerned, little or no flavorings were used with the many infiltrated products prepared.

In the following discussion the functionality as well as storage stability of the infiltrated foods was given more emphasis. Each infiltrated food, however, was tested by an informal taste panel to assure minimum organoleptic acceptability.

The Preparation of The Individual Infiltrated Foods

1. Pound Cake or Doughnuts

Of the two bakery items, pound cake was selected for infiltration and storage studies because it was one of the items in Phase I work that was successfully infiltrated by the positive pressure method. Cakes were purchased from a local market (Lagendorf United Bakers, Inc., San Francisco, California) and cut into 1 x 2 x 1/2 inch pieces to fit the die used for infiltration. From the results of the earlier studies, it was found that positive pressure infiltration required the pieces to be firm while under pressure within the die. Consequently, the cake pieces were placed in a 100°F oven for 1/2 hour to achieve the necessary firmness prior to infiltration.

A 1:1 ratio of butter frosting and CCC shortening, developed in Phase I work, was used as the filler for impregnating the cake pieces. The butter frosting was made from the following ingredients:

Ingredient	Percent by Weight
Confectioner's Sugar	64.5
CCC Shortening	25.2
Heavy Cream	10.3

To make the butter frosting, sugar was first thoroughly mixed with the shortening and then followed by the addition of the cream. The weighed lipid phase was melted, mixed with 0.25 percent by weight of lecithin and slowly blended into the butter frosting using a low-speed rotary beater. (Lecithin, A. E. Staley Company, Decatur, Illinois, was found in Phase I work to aid in emulsion formation and stability, resulting in better infiltration results. The blending temperatures were approximately 80°F for the butter frosting and 160°F for the lipid phase. It was important to keep the emulsion at a creamy consistency to achieve good penetration results; this was achieved by keeping the emulsion at a relatively constant temperature in the range of 115° to 120°F. At higher temperatures the components of the emulsion separated and at lower temperatures, the fat solidified.

This butter frosting-CCC mixture was placed over the piece of cake within the die and 100 pounds pressure applied for one minute to effect complete infiltration. A sample of the infiltrated pound cake is illustrated in Figure 4.

2. Pancakes or Waffles

Previous positive pressure infiltration work with waffles revealed that the shape of the waffles did not lend itself to uniform penetration or to removal of excess filler material, and consequently, pancakes were the item selected for infiltration and storage studies.

Pancakes were prepared from a mix (Betty Crocker Brand, General Mills, Inc., Minneapolis, Minnesota) and cooked in the FMC kitchen. The prepared pancakes were first cut into 1 x 1 x 1/2 inch pieces and air dried for one half hour at 100°F to achieve the firmness necessary for positive pressure infiltration.

Two filler formulations were tried with the pancakes and tested. The initial formula for infiltrating pancakes was the same butter frosting-CCC mixture used for the pound cake except with the addition of 0.1 percent of vanilla flavoring and 0.1 percent of maple flavoring (Both Schilling Brand, Mc Cormick and Company, Baltimore, Maryland.) These infiltrated pancakes were judged acceptable when freshly made, but after four months storage became rather hard and grainy, and for the most part rated unacceptable by the panel.

Another filler formula was tried with pancake to minimize the increase in firmness occurring during storage. The formula for this second filler was the 2:2:1 combination of peanut butter, red currant jelly and Myverol mixture used for infiltrating toast, and its preparation is discussed in that section. Successful positive pressure infiltration was achieved with this second filler formulation. A sample of the infiltrated pancake is also illustrated in Figure 4.

3. Toast or Crackers

Toast, because it was very similar to pound cake in texture, was the item selected for infiltration by the positive pressure method. Zwieback Toast (National Biscuit Company, New York, New York) was purchased and cut into 1 x 2 inch pieces for infiltration. Since this product was already in firm

condition, no further drying for tempering was necessary.

Peanut butter and jelly combination was found to be the most acceptable filler formulation used for infiltrating the dry toast. Grape, blackberry, strawberry, black raspberry and red currant jellies were mixed with the peanut butter and pressure infiltrated into the toast. Of the products tested, toast infiltrated with a 1:1 ratio of red currant jelly (Mary Ellen's Inc., Berkeley, California) and peanut butter (Skippy Brand, Corn Products Company, Alameda, California) received the best rating from an informal taste panel. Samples which contained a greater amount of peanut butter were rated too gummy, while those with a greater ratio of jelly were too sweet. To offset the natural oilness of the filler combination and to increase caloric content, 20 percent by weight of Myverol 18-00 was incorporated into the peanut butter-jelly mixture. This level of Myverol was found to be the maximum amount acceptable; the use of higher levels resulted in a noticeable waxy taste.

To make this filler, peanut butter and jelly were mixed at room temperature with a rotary beater until a homogenous mixture was obtained. Myverol, which had been heated to 200°F, was then added with rapid mixing. Continual mixing and constant heating at 125° was necessary to keep this filler at the desired creamy consistency.

4. Puffed Rice or Puffed Wheat

Puffed wheat and puffed rice made by the Quaker Company of Chicago, Illinois were purchased for the infiltration studies. Initial infiltration trials revealed that both foods could be infiltrated by the vacuum release method. In an informal poll of panel members, puffed rice was regarded as more acceptable as a cereal product,and as a result it was decided to select rice as the item for further penetration work.

The first infiltration attempts with puffed rice were to use a flavored emulsion so that the final product would resemble some of the flavored cereals now on the market.

Several flavored emulsions were tried, and in each case the final product was unsatisfactory. When the hot aqueous-lipid mixture came in contact with the puffed rice, the samples softened and collapsed, and as a result further work with emulsions was discontinued.

Pure lipid fillers such as CCC and Myverol were then tried. Less shrinkage was noted, but the flavor of the product was bland and not very acceptable. Several compatible oil soluble flavors were then incorporated into the lipid filler to enhance the final infiltrated product. Although these flavored products were some improvement, suitable flavoring levels could not be achieved. A strong burning after-taste was experienced with these products after eating several pieces.

Room temperature infiltration with other high caloric fillers materials was then attempted. It was found that honey could be successfully infiltrated by the vacuum release method. Further work with this filler was discontinued when it was revealed that the infiltrated product fell short of the caloric requirements.

Equally successful infiltration results were achieved using the high solute sugar syrup, Liquicane, with an increase in caloric value over honey, although the final product was still below the caloric requirements. Both infiltrated items were sticky, but from a taste standpoint, Liquicane was more preferable than honey.

Attempts were then directed toward reducing the stickiness and increasing the caloric content, and the best approach appeared to be by the use of a high caloric coating. A special commercial coating chocolate, supplied by the Ghiradelli Chocolate Company of San Francisco, California was tried and found to be ideal as far as coating was concerned; however, further work was necessitated when it was found that chocolate coating melted at 100°, and that more calories were needed in the coating. In subsequent tests a 3:1 chocolate-Myverol mixture proved to be the most promising. This chocolate-Myverol combination did not melt at 100° and was not considered too waxy tasting. When applied, this coating hardened quickly and served a three fold purpose, it made the product non-sticky, it kept the syrup from seeping out and it added the necessary calories to meet the 4.4 Kg-calories per gram requirement.

Temperature proved to be a critical factor in the application of the chocolate coating. A 140°F temperature had to be maintained for the chocolate-Myverol mixture. Below this temperature, the mixture was too thick, and above this temperature it was too thin.

5. Macaroni

The plan with macaroni was to fill the void with all of the ingredients except water that are needed to make Macaroni au Gratin so that this dish would be the result of hydration of the infiltrated macaroni. Elbow macaroni (Golden Grain Brand, Golden Grain Macaroni Company, San Leandro, California) was purchased from a local market for use in these trials.

The first emulsion tested was composed of powdered cheddar cheese (Beatreme 1326, Beatrice Foods Company), Purity 270 starch, and CCC. The lipid was melted and blended with the other ingredients using a rotary beater. This emulsion was then injected into the macaroni void using a hand pump. The resulting stuffed macaroni was cooked in boiling water for thirty minutes. At the end of this time the macaroni was cooked and a sauce had formed; however, all of the emulsion had not escaped from the macaroni, and the resulting product was somewhat gummy.

Next, a 3:1:1 ratio of the powdered cheddar cheese, Purity 270 starch, and a powdered shortening (Beatreme 1184-A, Beatrice Foods Company) was introduced into the macaroni void using the hand pump. The hydration product in this case was very satisfactory, since all of the filling ingredients had blended into the boiling water. The flavor of the sauce, however, was rather bland with only a slight suggestion of the cheese flavor. Nontheless, an informal taste panel rated this product as quite acceptable. The amount of filler that can be introduced into the macaroni void is such that, should only cheese be used, there would still not be a significant cheese taste upon hydration.

The filled product was coated with a thin layer of Myverol 18-00, both to keep the filler from spilling out of the macaroni and to add essential extra calories. The final product meets the 4.4 Kilogram-calories per gram minimum, but not the 4.4 Kilogram-calories per cubic centimeter minimum. Perhaps, if the filler were introduced into the void under greater pressure, the percent voids could be reduced sufficiently to increase the caloric content per cubic centimeter value of the finished product.

6. Chicken

Cooked and frozen chicken rolls composed of both light and dark meat were purchased, sawed into 1/2 inch slices, and then freeze-dried in the FMC pilot facilities. The dried slices were then cut into approximately one inch squares for subsequent infiltration procedure. Phase I infiltration work indicated that chicken could be successfully infiltrated by both positive pressure and the vacuum release techniques. Since the vacuum release method was the easier method of the two, it was decided to use this method exclusively to prepare infiltrated samples for test purposes.

Satisfactory infiltration of an emulsion could be achieved by the vacuum release method, but the infiltrated product was unsatisfactory due to shrinkage. The shrinkage occurred when the food sample came into contact with the aqueous phase of the emulsion. The use of viscous emulsions reduced shrinkage, but infiltration was not uniform and the product was hard to hydrate in water. Since partial hydration occurred with all the emulsions tried, and since a partially hydrated chicken would be more susceptable to spoilage, it was felt that it would be best to eliminate entirely the use of any water in the filler formulation.

A filler mixture containing CCC and Purity 270 starch powder was found to be ideal for infiltrating the freeze-dried chicken. This mixture did not contain any water and was more acceptable from a taste point of view than pure fat. When the infiltrated product was added to warm water, the fat-starch mixture hydrated to form a gravy base that enhanced the product taste and appearance.

This filler mixture was prepared by mixing equal weights of the Purity 270 starch and melted CCC. The best penetration results were achieved when the CCC-starch mixture was maintained at around 120°F during the infiltration by the vacuum release method.

7. Beef

From the first phase infiltration work with freeze-dried beef, it was found that satisfactory impregnation of low viscosity emulsions was possible by the vacuum release method. But, again, as in the case with chicken, the use of an aqueous phase resulted in partial hydration of the beef and consequently, the aqueous phase was eliminated in the make-up of the penetrating material. And, again, infiltrating with a 1:1 CCC-Purity 270 starch mixture was found to be the best solution for the same reasons discussed earlier. Using the six cycle, vacuum release method, complete infiltration of the beef was readily attained.

The beef used for the infiltration studies was purchased fresh from a local supplier. Since the infiltrated product had to be acceptable for direct consumption, the meat was first cooked to 145°F. center temperature before drying in the freeze dryer.

8. Freeze Dried Fish or Shrimp

Shrimp was the item selected for infiltration studies because of its ease of penetration. The best method for penetration into these samples was the six cycle vacuum-release method. As with beef and chicken samples, there was partial hydration of shrimp samples using aqueous-lipid emulsions, and once again the best filler material was found to be the 1:1 CCC-Purity 270 starch combination.

For preparing the infiltrated storage samples, medium-jumbo, freeze-dried cooked shrimp was purchased from the Kraft Foods Company of Chicago, Illinois.

9. Peas or Corn

Vacuum-release penetration trials were conducted with both freeze-dried peas and freeze-dried corn, using a 1:1 ratio of a white sauce and CCC as the penetrating emulsion. The white sauce was made from the following ingredients: milk-79.6%, oleomargarine-13.2%, and flour-7.2%. In both cases there was thorough penetration of the lipid phase, but only insignificant white sauce penetration. Further trials with this filler combination were discontinued, however, when it was discovered that the white sauce spoiled quickly.

In subsequent work it was found that both corn and peas could be easily infiltrated with the 1:1 CCC-Purity 270 filler used for infiltrating other foods. Although both infiltrated foods were considered bland, they both were still considered palatable when eaten directly. Upon rehydration, the lipid-starch combination formed a sauce with the water that complemented the products. The consensus of an informal taste panel indicated that infiltrated peas were more acceptable when eaten directly (dry) than the infiltrated corn; as a result, peas were selected for the storage studies.

Commercially available frozen peas were used for preparing the infiltrated samples. The peas were first cooked and then refrozen and freeze-dried prior to infiltration by the vacuum release method.

10. Asparagus or Green Beans

Infiltrated freeze-dried beans have proved to be rather tough and less acceptable, and for this reason, asparagus was selected for infiltration.

It was found that complete infiltration of the freeze-dried asparagus could be achieved with the six-cycle vacuum release method. An initial attempt was made to incorporate powdered sour cream (Beatreme 1038, Beatrice Foods Company, Chicago, Illinois) into the CCC-Purity 270 starch mixture. Satisfactory infiltration results were obtained with this formula, however, the hydrated product was quite chewy with an unacceptable flavor.

Asparagus was next infiltrated with the 1:1 CCC-Purity 270 starch mixture. This product was not quite as chewy and was more palatable when eaten, directly and rehydrated. As a result, asparagus samples were infiltrated with the CCC-Purity 270 starch mixture and placed into storage.

Samples used for the infiltration studies were prepared from fresh asparagus that was sliced, blanched, frozen and then freeze-dried on the pilot freeze-dryer. The infiltrated product is illustrated in Fig. 5.

11. Freeze-Dried Strawberries or Pineapple

It was found in the attempts to infiltrate freeze-dried pineapple that the filler materials penetrated only the cavities open to the exterior rather than through the cell walls. Besides the inconsistent penetration results, the extreme brittleness and hygroscopicity of the dried pineapple made handling difficult and less suitable for penetration purpose.

Freeze-dried strawberries were found to be easily infiltrated using the six cycle vacuum release method, but there were some difficulties experienced with the type of fillers employed. Whenever an aqueous-lipid emulsion was employed as a filler material the strawberries shriveled badly.

If pure lipid fillers such as CCC or Myverol 18-00 were used there was little shrinkage, but the accompanying waxy mouth feel masked any strawberry taste, and this product was rated very poor. Less shrinkage of the berries was experienced with a filler combination of Liquicane, CCC and Purity 270 starch, but the impregnated product was difficult to hydrate.

It appeared then that the best solution for infiltrating strawberries was to accept the 15 - 20% shrinkage that occurred when using plain Liquicane as a penetrant and coat the pieces with chocolate. The final infiltrated product resembled a chocolate coated candy product and rated very acceptable.

Complete infiltration of the Liquicane was achieved with the six cycle vacuum release technique. Before coating the infiltrated pieces, the excess sugar was drained off. The coating formula was the 3:1 chocolate-Myverol mixture used in coating puffed rice. A sample of the final product is illustrated in Fig. 6.

12. Freeze-Dried Apples or Peaches

It was found that both apples and peaches could be easily infiltrated by the vacuum release method, but that both samples exhibited a tendency to shrivel during the infiltration procedure. This tendency for shriveling was more marked with the peach slices. When using aqueous-lipid filler emulsions there was no difficulty in filling the voids with lipids, but the aqueous phase penetration of the peach slices was unsatisfactory regardless of emulsion viscosity. Because the results with apples appeared to be more promising, no further work was attempted with peaches. For this item, frozen diced apples were purchased and freeze-dried in the FMC pilot dryer.

The best apple dice penetration was achieved with low viscosity emulsions but was also accompanied by the greatest shrinkage. When high viscosity emulsions were employed the shrinkage of the product was reduced, but by the same token, the aqueous phase penetration was significantly reduced. Successful butter frosting-CCC shortening penetration of the apple dices were achieved, but the rehydrated product proved to be both sweet and greasy and not very appetizing.

A 1:1 ratio of CCC and confectioners sugar was tried and found to produce an infiltrated apple product that was acceptable both dry and rehydrated. 0.25% Lecithin was added to this mixture to aid in stabilization during the vacuum infiltration procedure. Further flavor enhancement was achieved when a light flavored coating was applied to the infiltrated pieces. The formula for the coating consisted of a 2:1 ratio of Purity 270 starch and granulated sugar that also contained 8.3% cinnamon and 2.1% nutmeg. When eaten directly, this product resembled a candied fruit, and when rehydrated, the finished item resembled and tasted like a spiced apple sauce dish.

13. Cottage Cheese or Scrambled Eggs

Initial infiltration work was done with freeze-dried scrambled eggs which were prepared in the pilot plant facilities according to U. S. Army Specifications LP/P Des. C-203-63 (1 Feb. 1963). The scrambled eggs were frozen in solid one half inch thick layers and freeze-dried, but upon removal from the dryer the layers crumbled into smaller particles which made subsequent handling difficult. Attempts were made to compress the dried eggs into bars which would then be infiltrated. The efforts to compress dried scrambled eggs, however, met with little success because of the high lipid content (22%) and granular structure. Pressures up to 10,000 psi were applied, but a good cohesive bar was not obtained. This compression treatment also succeeded in separating the egg lipids, and the compressed egg bar emerged from the die coated with fat that had migrated to the surface. Since these bars were in a sense partially infiltrated with a lipid, and further infiltration efforts met with little or no success, work was then directed toward producing infiltrated cottage cheese.

Large and small curd cottage cheese was purchased and freeze dried. The resulting dried product was of high quality, but of fragile structure and as such, did not lend itself to any infiltration procedures. Compression was again tried and it was found that a suitable cohesive bar could be obtained by placing a 10 gram sample in the 1 x 2 inch die under 2500 psi for 30 seconds. This bar was readily infiltrated with melted CCC using the vacuum release procedure, but taste tests revealed that further work was necessary to make the bars more acceptable.

The initial taste tests also revealed that bars made from small curd or cream style cottage cheese were more preferable than those made from large curd cottage cheese and as a result, small curd cottage cheese was used in further experiments.

Two approaches were followed in the development of an acceptable tasting infiltrated and compressed cheese bar. The addition of 20% powdered sugar to the cottage cheese resulted in a more flavorful bar and the addition

of an oil soluble pineapple flavoring to the CCC masked the greasy taste of the fat. Pineapple flavoring No. 17828 (Fritzsche Brothers New York, New York) added to the melted CCC at the rate of 0.8 ml per 1000 ml was judged to be the best formula used. This bar met the caloric requirements as well as being rated organoleptically accepted, and was tested only in dry form.

14. Dehydrated Beef Stew or Chicken with Rice.

The decision to produce infiltrated beef stew or chicken and rice was not made until the results of the taste panel evaluations with the stored chicken and beef were completed. The test results showed that both impregnated samples were stable and were equally acceptable when hydrated, but the panel expressed a significantly greater preference for beef in the dehydrated form. Because of the greater preference for beef, the decision was made to proceed with formulation of an infiltrated beef stew product.

Beef, potatoes, onions and peas were selected as the ingredients for infiltration. For the beef and pea components, the previously described infiltration procedures and filler formulae were used. Dehydrated onion flakes (Schilling Brand, McCormick Company, Baltimore, Maryland) were readily infiltrated with melted CCC using the six cycle vacuum release method, but attempts to infiltrate dehydrated potato flakes (Idahoan Brand, Idaho Fresh-Pak Potatoes, Lewisville, Idaho) met with little success. The relatively impervious surface and non porous structure of the dehydrated potatoes did not lend itself to any infiltration procedures. The potato pieces were more lipid coated than lipid infiltrated, and furthermore, the treated product did not meet the caloric requirements.

Since it was not possible to obtain a satisfactory impregnated potato, dried pre-cooked rice was used as a substitute. Minute Rice (General Foods, White Plains, New York), being of a porous structure, was readily infiltrated by the vacuum release method with melted CCC.

Upon completion of successful infiltration of the stew components various component mixtures were prepared and rehydrated to determine the most acceptable combination. On a dry weight basis of the infiltrated foods the following formula was found to be the most ideal; Rice-50%, Beef-30%, Peas-19%, Onions-1%. To promote better particle distribution and to reduce rehydration time, the beef used in the product combination was cut into 1/4 inch cubes prior to infiltration.

When this infiltrated combination was rehydrated and a gravy sauce was formed from the starch and lipid, the product resembled some of the prepared dinner mixes that are commercially available and accepted. Both the dry and rehydrated beef stew is illustrated in Fig. 7.

III. EVALUATION OF INFILTRATED FOODS

It was specified in the contract that upon achieving successful infiltration with each food, a series of special tests were to be performed. These tests can best be discussed under the following two headings: (A) Chemical and Physical Analysis of Infiltrated Foods and (B) Storage Stability Studies of Infiltrated Foods.

A. Chemical and Physical Analysis of Infiltrated Foods

Under this heading the following analyses were performed on all the infiltrated foods: (1) Chemical Analysis for Moisture, Protein, Fat, Ash; (2) Density; (3) Caloric Value; and (4) Equilibrium Moisture Value.

1. Moisture, Protein, Fat and Ash Content

The results of these four analyses are summarized on Table I and were run on freshly prepared samples. The following analytical procedures were used in the determinations:

Moisture Content:[1] Moisture content was determined by drying in a vacuum oven under a minimum vacuum of 28 inches of mercury for sixteen hours. To promote moisture removal, all samples were pulverized before drying. All determinations were run in triplicate.

Moisture contents are expressed on the dry basis.

Protein:[1] The Kjeldahl method for determining nitrogen was used in calculation of the protein content. Samples of infiltrated food were first dried and extracted with petroleum ether and then digested with sulfuric acid. Sodium sulfite and copper sulfate were used as catalysts in the digestion. The distilled ammonia was collected in boric acid and titrated with 0.1 N HCl, using methyl red indicator. Protein was then calculated from the following formula:

$$\frac{\text{ml HCl} \times 0.1 \times 0.017032 \times 100}{\text{weight of sample}} = \% \, NH_3 \times 5.14 = \% \text{ protein}$$

Fat:[2] Petroleum ether was used for determining the fat content of the infiltrated foods. Test samples were ground, weighed into tared Soxhlet thimbles and dried for two hours at 90°C. in air before extraction for six hours. Lipid values are expressed as percent of petroleum ether extract.

Ash:[1] The ash content of all the infiltrated foods was determined by ashing to constant weight in a muffle oven at 600°C. In most cases ashing was completed in less than three hours.

2. Density

Density calculations of the impregnated foods were calculated as apparent and true densities. The apparent density figures are based on the observed weight gain per cubic centimeter of the infiltrated product as compared to the original food. Samples were weighed to the nearest milligram on a Mettler Analytical Balance. Volume measurements were made with the aid of the ruler and are less accurate. To compensate for any high percent of error, apparent density measurements were made on ten randomly selected samples. Apparent density data are summarized on Table 2.

True densities were measured with the aid of a Beckman Model 420 Air Pycnometer. With the exception of shrimp, the volumes of weighed samples were measured using the one to two atmosphere operation. Shrimp exhibited high surface absorption activity that affected the accuracy of readings, and consequently, a one to two atmosphere helium purge was used. True densities of all the infiltrated foods are listed in Table 3.

Knowing the true and apparent density values, it is then possible to calculate porosity with the following formula:

$$\frac{\text{true density - apparent density}}{\text{true density}} = \text{Porosity}$$

By calculating porosity of both infiltrated and uninfiltrated foods, it is then possible to determine the fraction of voids filled by the following method:

Porosity of original food - porosity of impregnaced food = Fraction of voids filled.

Table 4 summarizes porosity values of the infiltrated and uninfiltrated foods and the fraction of voids filled.

3. Caloric Value

Caloric values of the infiltrated foods were calculated in terms of both weight and volume. Standard reference guides were used in determining these values[3]. In all cases the infiltrated foods yielded at least 4.4 Kilogram-calories per gram, but there were a few foods that did not approach the 4.4 Kilogram-calories per cubic centimeter.

Table 5 summarizes the caloric value of each uninfiltrated food, the caloric value of the respective filler and the resulting caloric density calculated on the basis of weight change.

The true density and porosity values calculated earlier were employed to determine the percent of food, filler and void, respectively, that make up one cubic centimeter of the infiltrated product. Knowing the percentages of the volume occupied by each, the Kilogram-calories per cubic centimeter of the infiltrated product was calculated from the following formula:

Kilogram-calories/gm x gm/lcc = Kg-cal/cc

Results of these calculations are summarized in Table 6.

Several foods failed to achieve the specified caloric density on a volume basis. In these cases there are more unfilled voids than filled voids. With rice, peas and strawberries, low initial caloric density with relative high porosity makes it difficult to achieve the high final caloric density. For two of these items, strawberries and rice, it was necessary to add a coating for supplementary calories. Possible increases in caloric value may be achieved by the application of more coatings; however, this avenue of approach was not followed since a heavily coated product would be more associated with a manufactured food rather than an infiltrated food. Based on practical limits of the infiltrating method, it does not appear that the specified caloric density on a volume basis will be achieved with puffed rice, macaroni, peas, strawberries and apples.

4. Equilibrium Moisture Values

Included in the chemical and physical evaluations was the determination of equilibrium relative humidity moisture contents for each infiltrated food at the three relative humidities. The method used for determining equilibrium moisture values was based on a technique first proposed by Wink [3], and modified by Levine and Fagerson [4]. The apparatus used was designed by Lampi [5] as a further modification of the preceeding methods and is illustrated in Figure 8.

A pint canning jar with a standard two piece metal lid (Ball Brothers) is used as a humidity chamber. The infiltrated food sample is placed on a plastic petri dish that is suspended over a saturated salt solution used for humidity regulation.

The three saturated salt solutions used for regulating humidity within the jars were as follows:

Salt	% R.H. at 20°C.
Lithium Chloride	11.1
Potassium Acetate	23.0
Potassium Carbonate	43.7

The outer upper end of the suspension wire is looped so that it can be hung on to the pan hook of a Mettler Balance. With this set-up, frequent weighings can be made to follow the course of equilibration without disturbing the inner contents of the jar.

The equilibrium moisture values for each infiltrated food at the three relative humidities along with the approximate equilibration time are summarized on Table 7.

. Storage Stability Studies of Infiltrated Foods

The evaluation of storage stability of the infiltrated foods involved three phases of analyses: chemical, microbiological and organoleptic studies.

The storage tests were designed to evaluate the effects of four months storage on the chemical, microbiological and organoleptic stability of the infiltrated products stored under the following three temperatures:

1. 20°C.
2. 38°C.
3. Cycling between -18° and +20°C. (For this cycling program, the following schedule was followed: 24 hours at 20°C, 24 hours at 18°C, 60 hours at +20°, 60 hours at -18°C.)

A secondary objective of the storage test was the determination of minimum storage precautions to be taken to avoid deterioration under the temperatures listed above.

To accomplish both objectives of the storage stability studies, three sets of each infiltrated food sample were prepared. One set of samples was stored in atmospheric oxygen (as is), a second set sealed under N_2 and a third set prepared with the addition of an anti-oxidant and stored in atmospheric oxygen. 0.077% of Tenox 6 (Eastman Chemical Company, Kingsport, Tennessee) based on the lipid filler weight was the anti-oxidant used in the third set of samples.

All samples prepared for the above storage conditions were sealed in standard 303 cans, and the cans were maintained at the three temperatures. Some of the larger infiltrated samples (beef, shrimp, chicken, cottage cheese and cake) were first loosely wrapped in aluminum foil to maintain better sample identity and to facilitate packing into the 303 cans.

1. Chemical Tests for Storage Stability

The chemical tests used to determine storage stability of the infiltrated foods were primarily tests to measure lipid deterioration. Since all the products were of high fat content, it was thought that the major source of off flavors and odors would be the result of lipid reactions. Chemical evidence of any lipid deterioration was determined by free fatty acid and peroxide value analyses. The procedures for these analyses were as follows:

Free Fatty Acids[2]

A one-gram sample obtained from the lipid analysis was first heated to get it into liquid form. Next, fifty milliliters of neutralized alcohol was added to the sample and brought to boiling. Two milliliters of phenolphein indicator were added, and the samples were then titrated with .01 N sodium hydroxide to a persistent pink color. Free fatty acids were then calculated and expressed as percent oleic acid using the following formula:

$$\% \text{ Oleic} = \frac{\text{ml of alkali} \times N \times 28.2}{\text{weight of sample}}$$

It is worth noting that in determining both the free fatty acid content and the peroxide values, some difficulty arose in determining the end point in samples where the fat had a color to it. An example of this would be macaroni and cheese in which the fat was orange in color.

Peroxide Values[2]

A one-gram sample obtained from the lipid analysis was dissolved in a 2:3 acetic acid-chloroform solution. One milliliter of saturated potassium iodide solution was added to the samples, after which they were placed in the dark for ten minutes. Next, fifty milliliters of .1 N hydrochloric acid was added and the samples titrated with .01 sodium thiosulfate to a water-white end point using starch as an indicator. Peroxide values as milliequivalents of peroxide per thousand grams of sample were calculated using the following formula:

$$\text{Peroxide value} = \frac{\text{ml of } Na_2S_2O_3 \times N \times 1000}{\text{weight of sample}}$$

The results of the free fatty acid and peroxide value determinations are summarized in Tables 3 and 9.

Except for the three foods listed, the peroxide value of most infiltrated foods were found to be less than 0.1. The results of the free fatty acid analyses, on the other hand, showed varying degrees of increases for all foods. Tests were also run on the filler materials stored under the same conditions as the infiltrated samples, and in all cases there were no observed significant changes in free fatty acid and peroxide values.

Considerable variations within samples were experienced in the lipid deterioration analyses, but generally the increases were relatively small. Samples stored under 38°C showed more change than at the other temperature and less deterioration was experienced with N_2 packing with freeze-dried foods. Mixed results were observed with the Tenox added samples. In the final analysis there was no observed off-taste due to lipid deterioration with any of the stored products; consequently, the values recorded must be within the limits of acceptability.

2. **Microbiological Studies**

Upon completion of the four month storage test, all infiltrated foods were analyzed to determine microbiological stability. The determination for evidence of microbial deterioration consisted of a careful visual examination for any macroscopic evidence of any microbial growth followed by cultivation and plate counting of infiltrated samples.

No mold growth or other macroscopic evidence of contamination or deterioration was observed with any of the stored samples, but the results of plate counts revealed both slight increases and decreases in microbial population. It must be mentioned here that in the course of preparing infiltrated food samples, no special procedures other than good hygenic food practices were followed.

Because of the high lipid content of the infiltrated foods and the high melting point of the lipids used, some difficulty was first experienced in making satisfactory water dilutions for plating purposes. The lipid fraction did not disperse or stay dispersed in room temperature suspensions and clogged pipettes during the plate innoculations. This difficulty was overcome when it was found that by heating the suspension solutions and

pipettes to 103-105°F the food and lipid were better dispersed, which allowed for more uniform innoculation.

Samples used for microbiological examinations were randomly selected from the respective storage containers and each sample was plated at two dilution levels.

From the sample thus prepared, total count determinations were made with Difco Plate Count following the procedures of the Standard Methods for the Examination of Dairy Products [6] and the Recommended Methods for the Microbiological Examination of Foods [7]. All innoculated plates were incubated at 30-35°C for 72 hours and then examined. Results of the plate count analyses together with the gram stains of the typical colonies observed are summarized in Tables 10 and 11. The increase in microbial population is one of the principle criteria of assessing bacterial deterioration in food. Because little or no increase in bacterial population was observed in the stored infiltrated samples, the indications are that little or no deterioration occurs as a result of microbiological activity. This conclusion is further substantiated by the analysis of the bacterial types encountered in the control and storage samples. The control samples most often revealed bacterial types commonly associated with handling contamination while the more resistant types of bacteria were observed in the storage samples. This evidence indicated that the infiltrated products did not support microbial growth and that good microbiological stability was achieved with all the infiltrated foods.

3. Organoleptic Evaluation

The third series of storage stability evaluations was the determination of organoleptic stability of the fourteen infiltrated foods. Upon completion of the four months storage tests, all samples were evaluated for organoleptic stability by comparison with the freshly prepared counterpart. The taste panel tests were designed to evaluate organoleptic stability at the three storage levels (packing environment) and temperatures (treatments) and determine the minimum precautions to be taken to avoid orgaloleptic deterioration of the infiltrated foods.

Storage samples were presented in two randomly selected groups, four or five samples in the morning and the balance in the afternoon of a given day. Each group of samples was compared with freshly prepared samples. Using the ballot shown in Figure 9, panel members were asked to denote their preference and difference between the control and storage samples. For calculation purposes, a rating of 1, 2, and 3 was assigned to the preference levels and a score from 1 through 5 for the difference levels.

For those samples requiring testing in the rehydrated form, 160°F water was added to the infiltrated product and allowed to simmer over low heat for 30 minutes. Before serving the warm rehydrated products to the panel, any excess gravy that was formed was drained off.

With the exception of the first product, pound cake, the taste panel consisted of 8 members who tasted all of the infiltrated products.

Some difficulties were encountered in achieving complete rehydration of the larger intact pieces of infiltrated foods, but this problem was easily overcome by reducing the size of the pieces before immersing in the 160°F water.

With three of the infiltrated foods, namely beef, shrimp and chicken, all of the dried infiltrated samples were not presented to the panel. Previous experiences and preliminary taste tests revealed a high degree of reluctance and resistance to tasting all the nine storage samples for each of these foods. In order not to antagonize panel members and still give some measure of acceptability of the three dry infiltrated foods, only two samples of each food in dry form were tested. These two samples selected represented the highest and lowest acceptability rating in the rehydrated form.

The taste panel results showed that the storage samples were generally considered different from the controls, but the differences did not affect the preferences. Because of varying panel responses to each food and storage condition, the taste panel results of each food will be discussed under its own heading. The taste panel data are summarized on Tables 12 through 44 . The conclusions drawn from the data are based on the t-test and two way analysis of variance.[8] Based on practical experience, a true value of 2 was assumed for preference and 0 for difference calculations. Conclusions were tested for significance at the 95% confidence level.

a. Pound Cake

Low average scores were recorded for samples stored at 38° and packed in N_2 and O_2. Of the two methods of packing, samples packed in O_2 were significantly unacceptable. Samples prepared with Tenox showed the best overall acceptability and would appear to qualify as the minimum precautionary procedure to avoid organoleptic deterioration.

b. Pancake

It was mentioned earlier that two separate filler formulas were used to infiltrate pancakes. The first infiltrated pancake samples became increasingly harder in texture during the four month storage test and were rejected by the panel members. It must be admitted that all the infiltrated pancakes are fairly firm because this firmness is necessary for the positive pressure infiltration method, but the change in texture was not anticipated. The primary objective of the second attempt was to reduce the storage-induced hardness with another tested formula.

Time limitations precluded complete tests with this second infiltrated sample. The filler formula for the pound cake (2:2:1 ratio of peanut butter, red currant jelly and Myverol) proved to be equally successful in infiltrating the pancake, and with essentially the same organoleptic value for the infiltrated product.

Besides a different filler formula, the second set of infiltrated pancakes were of higher initial moisture. It was thought that the hardness could be reduced with the higher initial moisture. The second set of samples was only stored two months and tested. Since the Tenox-treated samples did not produce any beneficial effect in the first tests, only two treatment levels were tested, atomospheric O_2 packing and packing under a N_2 atomsphere. The results from the tests with both samples are included in the appendix.

It can be concluded that pancakes can be successfully infiltrated to the specified caloric density. However, a major formula revision of the pancakes is required to achieve good textural stability in the infiltrated product.

c. Toast

For infiltrated toast, cycling storage temperatures resulted in best acceptability rating for all levels of packing. Although the Tenox-treated samples scored highest with the cycling storage treatment, low acceptance ratings were noted at the other storage temperatures. Near equal overall acceptance is noted with the O_2 and N_2 packed samples. Since N_2 packing represents an added step in the packaging procedure, the minimum packing requirement for organoleptic stability appears to be plain packaging of infiltrated toast in atmospheric O2.

d. Puffed Rice

The best overall ratings for stored samples of puffed rice were for those samples packed in atmospheric oxygen. Nitrogen packing of the infiltrated rice sample resulted in complete rejection of the samples stored under cycling temperatures. The reason for the total rejection of this sample is unknown. Of the samples stored with Tenox, the 20°C storage samples were disliked by panel members.

Based on overall storage results, the best method of packaging infiltrated rice appears to be by packaging in atmospheric oxygen.

e. Macaroni

Of the nine storage treatments for infiltrated macaroni two samples were significantly disliked according the the t-test; nitrogen packing under cycling storage and the atmospheric O2 pack stored at 20°C. The observed deviations for the above responses are not attributable to envirnoment or temperature and cannot be explained in any practical manner. The highest overall ratings for the infiltrated macaroni was achieved by the addition of Tenox and appears to be the minimum method of packaging for best quality retention of infiltrated macaroni.

f. Chicken

The analysis of the panel results with rehydrated chicken reveals that samples stored under N2 were rated equal to or better than the control samples. Samples stored under atmospheric oxygen also received acceptable ratings, but all the Tenox treated samples were rejected. Greater differences were also noted for the Tenox treated chicken, and it is possible that the level of Tenox used for this product may have affected the results. For infiltrated chicken the minimum method of storage appears to be packing in atmospheric oxygen, but the highest overall acceptability ratings were achieved with the samples packed under a N_2 atomsphere.

As mentioned earlier, panel testing of the dry infiltrated chicken was reduced to testing two samples with the control. The samples which had the highest and lowest ratings in the rehydrated tests were selected for testing in dry form. The 20°C stored in N_2 was rated highest, and the lowest rated product was the 38°C storage sample containing Tenox.

The numerical results of this test showed that the N_2 packed sample was slightly more preferable and more differences were noted with the Tenox added sample, both reflecting somewhat the rehydrated test results. Statistically speaking however, the panel could not distinguish any differences between the sample extremes in preference or difference within the 95% confidence limits.

Based on the overall results of the panel tests, storage at the infiltrated chicken in a N_2 atmosphere qualifies as the best method for maintaining organoleptic stability.

g. Beef

The best overall preference of the stored infiltrated beef samples was recorded with samples stored at 20°C, and lower overall acceptance was observed with samples stored under cycling conditions. A wide range of differences was noted with all the samples, but these differences did not appear to affect the preferences.

Although the panel members expressed a unanimous acceptance of the 20°C storage sample under N_2, the opinion was divided with the other N_2 packed samples at the other two storage temperatures.

With the Tenox added samples the 20°C and 38°C storage samples were rated acceptable. Cycling storage conditions resulted in the greatest variations in taste differences.

The 38°C-O_2 samples and the cycled-Tenox samples were compared with the control to test the acceptance of infiltrated beef in dry form. Results of this test showed that samples rated highest in rehydrated form, 38°-O2 was again preferred over the cycled Tenox sample, lowest rated when tested in rehydrated form.

Based on the overall acceptance at the three storage temperatures, atmospheric O_2 storage samples resulted in the least quality deterioration and appears to be the recommended method of packing for best quality retention.

h. Shrimp

When taste tested in rehydrated form, all infiltrated shrimp samples stored under atmospheric O_2 received the lowest ratings, and highest overall ratings were noted with samples stored under a N_2 atmosphere. Samples stored under cycling temperatures appear to be more acceptable than at the other temperatures. The Tenox-added samples were rated somewhat better than the plain samples stored in atmospheric O_2, but the beneficial effects were not noted at all storage temperatures.

On the basis of the highest overall ratings, it appears that infiltrated samples of shrimp must be maintained under a N_2 atmosphere for best quality retention.

Panel testing of the dry infiltrated shrimp, as in the case with chicken, and beef, was limited to two storage samples. The highest rated (20°-N_2)

and lowest rated (20°-Atmospheric O_2) of the rehydrated samples were presented with a freshly prepared control. In this test the panel results showed that more differences were noted in the 20°-N_2 sample with slightly lower preference. The statistical results, however, show that both samples were rated fairly close to the control and the indications are that when this product is eaten in dry form, panel members cannot distinguish too well between samples.

i. Peas

All storage samples of infiltrated peas were taste paneled in dry and rehydrated form. As can be expected, the panel members expressed a greater acceptance for the rehydrated product, and all samples were judged acceptable and very nearly equal to the control. In dry form however, two of the samples were less acceptable. Lower overall preference scores were noted with the 20°+O_2 and 38°+Tenox samples. The addition of Tenox to the infiltrated samples resulted in slightly better quality retention. The best quality retention in both dry and rehydrated form and at the three storage temperatures was achieved by storing the infiltrated peas under N_2. On the basis of these results, storage of infiltrated peas under N_2 appears to be the minimum method for preventing quality deterioration.

j. Asparagus

Panel tests with infiltrated asparagus revealed that the product, when rehydrated, was judged to be inferior to the fresh control. In dry form, however, most samples were judged acceptable. A major contributing factor for the rejection of the hydrated samples was the lack of uniform rehydration. Loss of rehydratability is associated with storage deterioration in many freeze-dried foods, and may be the case with freeze-dried asparagus. Further loss of rehydratability can then be expected when asparagus fibers are coated and infiltrated with a lipid.

Based on the overall results, indications are that limited acceptability can be expected with infiltrated asparagus.

k. Strawberries

With one exception, panel members rated storage samples very nearly equal to the controls. Significant rejection was noted for samples stored under N_2 at 38°C. For some reasons unknown, the flavor of these samples was not acceptable. All Tenox-added samples were rated alike and acceptable, but less preferred than those samples stored under atmospheric oxygen.

Aside from several comments regarding the waxy taste of the chocolate, the infiltrated chocolate samples were considered highly acceptable as a confectionery item. For this product, best overall organoleptic stability can be achieved by packaging in atmospheric oxygen.

l. Apples

The tests with dry and cooked infiltrated apples showed that the dry storage samples were rated equal to the control. When infiltrated apples were presented in rehydrated form there was considerable variation

in response. This variation in response is not consistent and indicates that both storage temperature and environment have a significant effect on quality retention. It does not appear then, that there is a packaging procedure which will minimize quality deterioration at the three storage temperatures for this infiltrated product. Indications are that major reformulations are required to produce a stable infiltrated apple product.

m. Cottage Cheese

The results of the panel testing with compressed and infiltrated cottage cheese reveal that very little organoleptic deterioration took place during storage. On the basis of storage temperature, higher overall acceptance was achieved at 20°C and on the basis of environment, samples with Tenox were considered equal to or better than the control.

Minimum acceptable stability of infiltrated cottage cheese samples can be achieved under atmospheric O_2 packaging, but greater acceptability will be accomplished by the addition of Tenox.

Cottage Cheese in compressed and infiltrated form was not recognized on sight as a familiar food, but on the whole most panel members found this infiltrated product to be very acceptable.

n. Beef Stew

With the exception of the samples mentioned at 38°C, practically all panel members rated storage samples as being very comparable to the control. The 38°C storage samples were judged to be slightly inferior, indicating that storage temperature had an effect on the quality. Of the samples stored at 38°C, equal perference was shown for the samples packed under N_2 and treated with Tenox, and both were rated higher than the samples stored under atmospheric O_2.

The addition of Tenox appears to offer minimum quality stability. However, on the overall analysis, storage under a nitrogen atmosphere results in the highe acceptability rating.

IV. SUMMARY

The objective of this study was the investigation of methods for infiltrating porous freeze-dried foods with high caloric fillers to achieve a total caloric density of 4.4 Kilogram-calories per gram and 4.4 Kilogram-calories per cubic centimeter. The first phase of the study was concerned with the development of filler formulas and penetration methods with various foods. The second phase of work dealt with the evaluation and storage stability studies of fourteen infiltrated foods.

The overall results of the studies indicate that porous dried foods can be infiltrated to higher caloric densities with reasonable initial acceptability. The results can be summarized as to their bearing on the following:

1. Penetration Procedures.

   Three methods for infiltrating foods were established, vacuum release, positive pressure and mechanical injection. The vacuum release method is best suited for infiltrating freeze-dried foods with low viscosity fillers. Positive pressure infiltration can only be applied to firm food products or products made firm, and the best infiltration results are obtained with high viscosity filler combinations. Mechanical injection is the only method of filling the voids of one item (elbow macaroni) and is the only method where a powdered filler material was used. The methods of infiltrating each of the respective foods can be adapted to commercial operations yielding 500 Kilograms per hour.

2. Foods for Infiltration

   Out of the 24 possible foods, the required number (14) were infiltrated with high calorie fillers with good or moderate results. Eleven foods met the requirements as to organoleptic acceptability in the dried and/or rehydrated form. For two foods, successful infiltration was possible, but equal acceptability in both the dried and rehydrated forms was not obtained. With one item (pancake), the basic porous food itself lacked stability.

3. Filler Formulas

   Filler materials used for the infiltration materials can be formulated from commercially available and F.D.A. approved ingredients. By the proper combination of these products, stable and organoleptically acceptable filler combinations can be formulated for each food.

4. Caloric Values of Infiltrated Foods

   All the foods studied were infiltrated to yield 4.4 Kilogram-calories per gram but not all could be infiltrated to yield 4.4 Kilogram-calories per cubic centimeter. With those foods that failed the caloric requirements on a volume basis, there were more unfilled voids than filled voids.

5. Stability of Infiltrated Foods

All infiltrated foods exhibited good storage stability on the basis of chemical and bacteriological analyses.

Taste tests comparing freshly prepared samples with samples stored for four months revealed that organoleptic stability was achieved for most foods with some minor exceptions. In these instances, the indications are that good storage stability can be achieved by minor revisions in the filler combination and in one case by a change in the formulation of the food to be infiltrated.

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TABLE 1

ORIGINAL FOOD ANALYSIS
PER 100 GM IMPREGNATED SAMPLE

FOOD	%MOISTURE (1)	%PROTEIN (2)	%FAT (3)	%ASH (4)
Pound Cake	1.87	2.61	46.84	0.16
Pancake-1st Test	6.38	6.97	28.61	3.49
Rerun-2nd Test	12.27	13.27	28.63	2.87
Zwieback Toast	15.20	10.89	22.65	1.30
Puffed Rice	7.03	3.95	23.59	0.79
Macaroni	7.81	11.81	23.07	1.06
Freeze-Dried Chicken	2.37	24.61	60.78	1.44
Freeze-Dried Beef	1.88	34.75	53.16	1.26
Freeze-Dried Shrimp	3.44	26.69	50.72	1.11
Freeze-Dried Peas	1.39	3.31	63.80	0.56
Freeze Dried Asparagus	2.46	1.86	64.83	0.54
Strawberries	11.25	2.45	12.87	0.91
Apples	2.03	0.41	40.10	0.22
Cottage Cheese	1.60	36.81	35.47	2.95
Stew	3.89	13.84	43.65	0.66

(1) AOAC, 20.008, p. 264
(2) AOAC, 2.033 Total Nitrogen Official, p.12
(3) AOAC, 22.032, p.287
(4) AOAC, 22.010 Ash Official, p.284

TABLE 2

APPARENT DENSITIES OF INFILTRATED FOODS

	Unimpregnated Density (gm/cc)	Impregnated Density (gm/cc)	Average Weight Gain (gm/cc)
Pound Cake	0.37	0.88	0.51
Pancake (1st Test Only)	0.48	0.92	0.44
Zwieback Toast	0.22	0.93	0.71
Puffed Rice	0.01	0.43	0.42
Macaroni (Dry)	0.29	0.47	0.18
Chicken*	0.39	0.89	0.50
Beef*	0.44	0.99	0.55
Shrimp*	0.31	1.15	0.84
Peas*	0.05	0.16	0.11
Asparagus*	0.06	0.58	0.52
Strawberries*	0.08	0.95	0.87
Apples*	0.14	0.86	0.66
Cottage Cheese* (Compressed Bar)	1.20	1.45	0.25
Beef Stew (Calculated on Basis of Following Ingredients by Weight.)	0.50	0.79	0.29
Rice (50%)	0.72	0.97	0.25
Beef* (30%)	See Above		
Peas* (19%)	See Above		
Onions (1%)	(Not Calculated - onion pieces highly irregular in shapes and not possible to calculate.)		

*Freeze Dried

TABLE 3

TRUE DENSITIES OF INFILTRATED FOODS†

Food	Unimpregnated Density (gm/cc) (1)	Impregnated Density (gm/cc) (2)	Average Change in Density (2 - 1)
Pound Cake	1.41	1.22	-0.19
Pancake (1st Test Only)	1.45	1.27	-0.18
Zwieback Toast	1.38	1.26	-0.08
Puffed Rice	0.37	1.20	0.83
Macaroni (Dry)	1.37	1.23	-0.14
Chicken*	1.32	1.09	-0.23
Beef*	1.39	1.15	-0.24
Shrimp*	1.95	1.25	-0.70
Peas*	1.26	1.46	0.20
Asparagus*	1.22	0.90	-0.32
Strawberries*	2.01	1.32	-0.69
Apples*	0.58	1.18	0.60
Cottage Cheese* (Compressed Bar)	1.30	1.20	-0.10
Beef Stew (Calculated on Basis of Following Ingredients by Weight.)	0.84	0.94	0.06
Rice (50%)	0.37	0.52	0.17
Beef* (30%)	See Above		
Peas* (19%)	See Above		
Onion (1%)	1.45	1.21	-0.24

*Freeze Dried
†By Pycnometer Method

TABLE 4

POROSITY MEASUREMENTS

Food	Initial Porosity (Uninfiltrated Food)	Final Porosity (Infiltrated Food)	Fraction of Voids Filled
ound Cake	0.74	0.28	0.46
ancake	0.67	0.28	0.39
wieback Toast	0.84	0.11	0.73
uffed Rice	0.98	0.64	0.34
acaroni	0.79	0.62	0.17
nicken*	0.70	0.18	0.52
eef*	0.68	0.14	0.54
hrimp*	0.84	0.08	0.76
eas*	0.96	0.89	0.07
sparagus*	0.95	0.36	0.59
trawberries*	0.96	0.28	0.68
pples*	0.75	0.32	0.43
ottage Cheese*	0.08	0.04	0.04

Freeze-dried

TABLE 5

CALORIES BY WEIGHT

Food	Kg-cal/gm non-infiltrated sample	% by wt. of final product	Aqueous-Lipid Phase	Kg-cal/gm of filler	% by wt. of final product	Kg-cal/gm impregnated product
Pound Cake	4.3	42.0	Butter frosting - CCC	6.8	58.1	5.8
Pancake	3.5	52.0	Butter Frosting - CCC	6.8	48.1	5.1
Zwieback Toast	3.9	24.0	Peanut Butter - Jelly - Myverol	4.7	76.1	4.5
Puffed Rice	3.9	1.9	Sugar Chocolate-Myverol	3.9 5.7	46.1 52.0	4.8
Macaroni	3.8	61.3	Cheese-Starch-Pwd. Fat Myverol	6.3 7.0	3.5 35.2	5.0
Freeze-Dried Chicken	5.2	44.0	Starch - CCC	6.3	56.0	5.8
Freeze-Dried Beef	5.7	44.0	Starch - CCC	6.3	56.0	6.0
Freeze-Dried Shrimp	3.8	27.0	Starch - CCC	6.3	73.0	5.6
Freeze-Dried Peas	3.8	29.0	Starch - CCC	6.3	71.0	5.5
Freeze-Dried Asparagus	2.7	10.0	Starch - CCC	6.3	90.0	6.0
Strawberries	3.7	9.0	Sugar Chocolate-Myverol	3.9 5.7	41.8 49.2	4.8
Apples	3.5	18.0	Conf. Sugar - CCC Starch - Gran. Sugar	6.5 3.7	78.9 3.1	5.8
Cottage Cheese (with 20% powd. sugar)	4.0	83.0	CCC	8.8	17.0	4.8
(Ingredients by Wt.)						
Stew						5.6 (avg.)
F-D Beef (30%)	See above					
F-D Peas (19%)	See above					
Onions (1%)	3.47	66.0	CCC	8.8	34.0	5.3
Rice (50%)	3.82	70.0	CCC	8.8	30.0	5.3

TABLE 6

CALORIES PER CUBIC CENTIMETER

Food	Kg-cal/cc non-infiltrated sample	% by vol. of final product	Filler	Kg-cal/cc of filler	% by vol. of final product	% void in infiltrated product	Kg-cal/cc impregnated product
Pound Cake	1.6	26	Butter frosting - CCC	3.5	46	28	5.1
Pancake	1.7	33	Butter frosting - CCC	3.0	39	28	4.7
Zwieback toast	0.9	16	Peanut butter-jelly-Myverol	3.3	73	11	4.2
Puffed Rice	0.4	2	Sugar-Chocolate-Myverol	2.02	34	64	2.1
Macaroni	1.1	21	Cheese-starch-pwd. fat-Myverol	1.2	17	62	2.3
Freeze-dried Chicken	2 1	30	Starch - CCC	3.2	52	18	5.3
Freeze-dried Beef	2.5	32	Starch - CCC	3.5	54	14	6.0
Freeze-dried Shrimp	1.2	16	Starch - CCC	5.3	76	8	6.5
Freeze-Dried Peas	0.2	4	Starch - CCC	0.7	7	89	0.9
Freeze-dried Asparagus	1.6	5	Starch - CCC	3.3	59	36	4.9
Freeze-dried Strawberries	0.03	4	Sugar-Chocolate-Myvarol	3.26	68	28	3.3
Freeze-dried Apples	0.5	25	Conf. sugar-CCC-Starch-Gran. Sugar	3.3	43	32	3.8
Cottage Cheese*	5.2	95	CCC	1.5	4.9	0.1	6.5
Beef Stew			CCC				5.1 (Estimated Value

* Compressed at 2500 psi/30 seconds - formula included 25% powdered sugar

TABLE 7

EQUILIBRIUM MOISTURE CONTENTS OF IMPREGNATED FOODS†

FOOD	INIT. MOISTURE CONTENT	% R.H. STORAGE	% H_2O†† AT EQUIL.	APPROXIMATE EQUILIBRIUM TIME (WEEKS)
POUND CAKE	1.87	11.1	0.99	12
		23.0	1.55	12
		43.7	2.44	12
PANCAKE	6.38	11.1	1.64	20
		23.0	2.23	16
		43.7	3.88	18
TOAST	15.20	11.1	2.05	28
		23.0	3.32	28
		43.7	5.33	28
PUFFED RICE	7.03	11.1	4.02	30
		23.0	4.63	30
		43.7	6.29	30
MACARONI	7.81	11.1	1.96	12
		23.0	4.53	10
		43.7	7.54	12
CHICKEN*	2.37	11.1	1.86	20
		23.0	2.74	20
		43.7	4.07	20
BEEF*	1.88	11.1	2.04	24
		23.0	3.03	24
		43.7	4.87	24
SHRIMP*	3.44	11.1	2.74	32
		23.0	3.71	32
		43.7	5.38	32
PEAS*	1.39	11.1	0.98	6
		23.0	1.59	8
		43.7	2.52	10
ASPARAGUS*	2.46	11.1	1.49	8
		23.0	2.40	8
		43.7	3.19	8
STRAWBERRIES*	11.25	11.1	7.06	22
		23.0	7.65	22
		43.7	9.61	22
APPLES*	2.03	11.1	1.23	8
		23.0	1.51	8
		43.7	2.56	8
COTTAGE CHEESE*	1.60	11.1	1.48	14
		23.0	1.80	14
		43.7	3.01	14
BEEF STEW*	3.89	11.1	2.60	8
		23.0	3.44	8
		43.7	5.80	6

† Moisture Content on Dry Basis by AOAC Method, 9th Edition, 1960, Page 264 20.008.

†† Equilibrium Storage Temperature 20°C.

* Freeze Dried.

TABLE 8

FREE FATTY ACIDS[1] IN FRESH AND FOUR-MONTH STORAGE SAMPLES
(EXPRESSED AS PERCENT OLEIC ACID)

FOOD	FRESH IMPREGNATED SAMPLE	STORAGE TEMPERATURES AND PACKING CONDITIONS								
		STORED IN O_2			STORED IN N_2			STORED IN O_2 WITH TENOX		
		20°C.	38°C.	-18+20°C.	20°C	38°C.	-18+20°C.	20°C.	38°C.	-18+20°C.
Pound Cake	.239	.326	.424	.283	.290	.258	.313	.255	.502	.376
Pancake-1st run	.269	.373	.395	.589	.381	.459	.486	.474	.528	.363
*Rerun -2nd run	.826	.541	.398	.728	.720	1.189	1.104	-	-	-
Zwieback Toast	.859	1.033	1.175	.877	.996	1.177	.861	.994	1.975	1.095
Puffed Rice	1.067	1.058	1.229	1.224	1.119	1.367	1.203	1.195	1.291	1.168
Macaroni	2.170	2.029	2.489	2.643	2.1[illegible]0	2.409	2.268	2.003	[illegible] 143	2.330
Freeze-Dried Chicken	.170	.231	.255	.242	.234	.233	.298	.165	.216	.277
Freeze-Dried Beef	.227	.248	.276	.280	.201	.189	.233	.171	.193	.205
Freeze-Dried Shrimp	.246	.235	.262	.251	.276	.312	.277	.294	.300	.309
Freeze-Dried Peas	.432	.482	.502	.407	.468	.428	.503	.471	.508	.489
Freeze-Dried Asparagus	.310	.337	.372	.350	.381	.302	.404	.404	.380	.507
Strawberries	1.378	1.915	2.740	1.689	1.754	2.412	1.631	1.471	2.287	1.847
Apples	.498	.658	.964	.727	.676	.801	.823	.554	.822	.628
Cottage Cheese	.509	.656	.628	.617	.812	1.138	1.653	1.286	1.396	2.052
Stew	1.336	2.292	2.135	1.377	1.733	1.548	1.626	2.193	2.191	2.644

(1) AOCS, Official Method, Ca-5a-40. Revised, 1963.

* Results on 2 months storage only - Tenox samples not run.

TABLE 9

PEROXIDE VALUE IN FRESH AND FOUR MONTH STORAGE SAMPLES
(EXPRESSED AS MILLIEQUIVALENTS OF PEROXIDE PER 1000 GRAMS OF LIPID)

FOOD	FRESH IMPREGNATED SAMPLES	STORAGE TEMPERATURES AND PACKING CONDITIONS								
		STORED IN O_2			STORED IN N_2			STORED IN O_2 WITH TENOX		
		20°C.	38°C.	-18+20°C.	20°C.	38°C.	-18+20°C.	20°C.	38°C.	-18+20°C.
Peas	.714	1.110	1.036	1.078	1.250	1.123	1.566	1.394	.611	.690
Asparagus	.213	.610	.593	.414	.727	.444	.496	.716	.423	.697
Cottage Cheese	.277	.371	.696	.190	.397	.288	.414	.322	.527	.275

For all other foods peroxide values were found to be less than 0.10

TABLE 10

MICROBIOLOGICAL EXAMINATION

Food	Control (Fresh Samples)		Four-month Storage Samples		
	Plate Count	Type	Storage Conditions	Plate Count	Type
Pound Cake	<10/gm	gram positive cocci	O_2 20° C.	<10/gm	
			38° C.	<10/gm	
			-18 +20 °C.	<10/gm	
			N_2 -18 +20 °C.	<10/gm	
			O_2 Tenox 20° C.	<10/gm	
Pancake	10/gm	gram positive cocci	O_2 20° C.	<10/gm	
			38° C.	<10	
			-18 +20 °C.	<10	
			N_2 -18 +20 °C.	<10/gm	
			O_2 Tenox 20° C.	10/gm	gram positive rods - Bacillus sporeforms
Toast	10/gm	gram variable cocci	O_2 20° C.	<10/gm	
			38° C.	<10/gm	
			-18 +20 °C.	<10/gm	
			N_2 38° C.	<10/gm	
			O_2 Tenox 38° C.	<10/gm	
Puffed [illegible]	10/gm	gram positive rods Bacillus	O_2 20° C.	<10/gm	
			38° C.	<10/gm	
			-18 +20 °C.	<10/gm	
			N_2 -18 +20 °C.	<10/gm	
			O_2 Tenox 20° C.	<10/gm	
Macaroni	20/gm	gram negative and positive cocci and some rods	O_2 20° C.	10/gm	gram positive and negative cocci
			38° C.	10/gm	gram positive cocci
			-18 +20 °C.	<10/gm	
			N_2 20° C.	<10/gm	
			O_2 Tenox -18 +20 °C.	<10/gm	
F-D Chicken	<10/gm	gram positive cocci	O_2 20° C.	20/gm	gram negative cocci
			38° C.	50/gm	gram negative cocci
			-18 +20 °C.	<10/gm	
			N_2 -18 +20 °C.	<10/gm	
			O_2 Tenox 38° C	<10/gm	
F-D Beef	16/gm	gram positive cocci and some rods	O_2 20° C.	900/gm	gram negative rods - some spores
			38° C.	500/gm	gram negative rods
			-18 +20 °C.	50	" " "
			N_2 -18 +20 °C.	45/gm	" " "
			O_2 Tenox 38° C.	480/gm	gram positive rods - Bacillus
F-D Shrimp	240/gm	gram variable cocci	O_2 20° C.	50/gm	gram positive cocci and rods
			38° C.	20/gm	gram positive cocci
			-18 +20 °C.	<10/gm	
			N_2 -18 +20 °C.	<10/gm	
			O_2 Tenox 20° C.	<10/gm	

TABLE I

MICROBIOLOGICAL EXAMINATION

Food	(Control (Fresh Sample)		Four-month storage Samples		
	Plate Count	Type	Storage Conditions	Plate Count	Type
Peas	10/gm	gram positive cocci	O_2 20°C.	10/gm	gram positive short rods - some spore forming
			O_2 -18 +20°C.	10/gm	gram positive rods
			N_2 20°C.	10/gm	spreading colonies, gram negative rods
			N_2 38°C.	2400/gm	gram negative rods & some gram negative cocci
			O_2 Tenox 38°C.	10/gm	spreading colonies, gram positive rods
Asparagus	10/gm	gram positive cocci	O_2 20°C.	100/gm	gram positive cocci
			O_2 38°C.	1000/gm	gram positive cocci
			N_2 20°C.	10/gm	gram positive rods
			N_2 -18 +20°C.	100/gm	gram positive rods
			O_2 Tenox 38°C.	10/gm	gram positive cocci
Strawberries	1000/gm	gram negative rods in chain	O_2 20°C.	3000/gm	gram negative rods
			O_2 38°C.	2000/gm	gram positive rods
			N_2 20°C.	1000/gm	gram positive rods
			N_2 38°C.	2000/gm	gram negative rods
			O_2 Tenox -18 +20°C.	2000/gm	gram positive rods
Apples	3000/gm	gram positive diplococci	O_2 20°C.	10/gm	gram positive rods
			O_2 38°C.	10/gm	gram positive rods
			N_2 -18 +20°C.	1000/gm	gram positive rods
			O_2 Tenox 20°C.	300/gm	gram positive rods
			O_2 Tenox 38°C.	2000/gm	gram positive rods
Cottage Cheese	10/gm	gram positive rods	O_2 20°C.	10/gm	gram negative rods - some spore forming
		rods	O_2 38°C.	1000/gm	gram negative rods
			O_2 -18 +20°C.	10/gm	gram negative rods
			N_2 20°C.	1800/gm	gram negative rods
			O_2 Tenox -18 +20°C.	10/gm	gram positive rods - some spore forming.
Stew	200/gm	gram positive cocci	O_2 20°C.	10/gm	gram positive cocci
			O_2 38°C.	400/gm	gram positive cocci
			O_2 -18 +20°C.	300/gm	gram positive cocci
			O_2 Tenox -18 +20°C.	10/gm	gram positive cocci
			N_2 20°C.	10/gm	gram positive cocci
Pancake Re-run (Second Test)	5000/gm	gram positive cocci	O_2 20°C.	10/gm	gram positive - short rods
			O_2 38°C.	10/gm	gram positive - short rods
			O_2 -18 +20°C.	1000/gm	gram negative - short rods
			N_2 [illegible]	[illegible]/gm	gram positive - rods

TABLE 12

TASTE PANEL DATA

POUND CAKE

Means of Scores

Preference

	-18° C.	20° C.	38° C.
O_2	2.17	1.75	1.25
N_2	1.83	1.58	1.42
T	2.08	1.75	2.25

Difference

	-18° C.	20° C.	38° C.
O_2	1.92	2.67	2.92
N_2	2.75	2.50	2.50
T	2.58	2.50	2.92

Variance in Scores

Preference

	-18° C.	20° C.	38° C.
O_2	.52	.75	.39
N_2	.70	.63	.45
T	.81	.57	.75

Difference

	-18° C.	20° C.	38° C.
O_2	.63	.61	.99
N_2	.57	.82	1.00
T	.63	1.00	.99

TABLE 13

STATISTICAL ANALYSIS OF TASTE PANEL DATA

POUND CAKE

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
	20° C.	-1.00	1.796	2.201	3.106
O2	38° C.	-4.18	1.796	2.201	3.106
-18	+20 °C	0.80	1.796	2.201	3.106
	20° C	-1.82	1.796	2.201	3.106
N_2	38° C	-3.02	1.796	2.201	3.106
-18	+20 °C	-0.69	1.796	2.201	3.106
	20° C	-1.15	1.796	2.201	3.106
Tenox	38° C.	1.00	1.796	2.201	3.106
-18	+20 °C	0.32	1.796	2.201	3.106

[1]observed [2]confidence

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
	20° C	11.87	1.796	2.201	2.718
O_2	38° C	10.14	1.796	2.201	2.718
-18	+20 °C	8.37	1.796	2.201	2.718
	20° C	9.57	1.796	2.201	2.718
N_2	38° C	8.66	1.796	2.201	2.718
-18	+20 °C	12.64	1.796	2.201	2.718
	20° C	8.66	1.796	2.201	2.718
Tenox	38° C	10.14	1.796	2.201	2.718
-18	+20 °C	11.29	1.796	2.201	2.718

Source of variation	DF	SS	MS
Treatments	2	3.19	1.59
Levels	2	3.35	1.68
Cells	(8)	(11.02)	
Treatments x levels	4	4.48	1.12
Within subgroups	99	61.08	.62
Total	107	72.10	

Source of variation	DF	SS	MS
Treatments	2	2.39	1.19
Levels	2	.50	.25
Cells	(8)	(8.67)	
Treatments x levels	4	5.78	1.44
Within subgroups	99	79.58	.80
Total	107	88.25	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	2.58	3.1
F-Ratio MS(T x L)/MS(Within) =	1.82	2.49
F-Ratio MS(Levels)/MS(Within) =	2.72	3.1

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	1.49	3.1
F-Ratio MS(T x L)/MS(Within) =	1.80	2.49
F-Ratio MS(Levels)/MS(Within) =	.31	3.1

TABLE 14

TASTE PANEL DATA

PANCAKE (1st Run)

Means of Scores

Preference

	-18° C.	20° C.	38° C.
O_2	1.75	1.13	1.13
N_2	1.38	1.13	1.38
T	1.25	1.50	1.25

Difference

	-18° C.	20° C.	38° C.
O_2	2.13	2.50	3.00
N_2	2.38	3.00	2.88
T	2.25	2.00	2.75

Variance in Scores

Preference

	-18° C.	20° C.	38° C.
O_2	.50	.13	.13
N_2	.27	.13	.27
T	.21	.29	.21

Difference

	-18° C.	20° C.	38° C.
O_2	1.27	1.14	.66
N_2	1.70	1.43	1.55
T	1.64	.57	1.07

TABLE 15

STATISTICAL ANALYSIS OF TASTE PANEL DATA

PANCAKE

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2	20° C.	-7.00	±1.895	±2.365	±3.499
	38° C.	-7.00	1.895	2.365	3.499
-18	+20 °C	-1.00	1.895	2.365	3.499
N_2	20° C	-7.00	1.895	2.365	3.499
	38° C	-3.42	1.895	2.365	3.499
-18	+20 °C	-3.42	1.895	2.365	3.499
Tenox	20° C	-2.65	1.895	2.365	3.499
	38° C.	-4.58	1.895	2.365	3.499
-18	+20 °C	-4.58	1.895	2.365	3.499

[1]observed [2]confidence

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2	20° C	6.61	±1.895	±2.365	±2.998
	38° C	9.17	1.895	2.365	2.998
-18	+20 °C	5.34	1.895	2.365	2.998
N_2	20° C	7.10	1.895	2.365	2.998
	38° C	6.52	1.895	2.365	2.998
-18	+20 °C	5.16	1.895	2.365	2.998
Tenox	20° C	7.48	1.895	2.365	2.998
	38° C	7.51	1.895	2.365	2.998
-18	+20 °C	4.97	1.895	2.365	2.998

Source of variation	DF	SS	MS
Treatments	2	.69	.35
Levels	2	.03	.01
Cells	(8)	(2.78)	
Treatments x levels	4	2.06	.51
Within subgroups	63	14.88	.24
Total	71	17.65	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	1.47	3.15
F-Ratio MS(T x L)/MS(Within) =	2.18	2.53
F-Ratio MS(Levels)/MS(Within) =	.06	3.15

Source of variation	DF	SS	MS
Treatments	2	4.75	2.38
Levels	2	2.08	1.04
Cells	(8)	(9.25)	
Treatments x levels	4	2.42	.60
Within subgroups	63	78.63	1.25
Total	71	87.88	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	1.90	3.15
F-Ratio MS(T x L)/MS(Within) =	.48	2.53
F-Ratio MS(Levels)/MS(Within) =	.83	3.15

TABLE 16

TASTE PANEL DATA

*PANCAKE (SECOND RUN)

Means of Scores

Preference

	-18°C.	20°C.	38°C.
O_2	2.00	1.63	1.25
N_2	1.38	1.63	1.38

Difference

	-18°C.	20°C.	38°C.
O_2	2.38	2.50	2.38
N_2	2.38	2.38	2.38

Variance in Scores

Preference

	-18°C.	20°C.	38°C.
O_2	.29	.27	.21
N_2	.55	.55	.55

Difference

	-18°C.	20°C.	38°C.
O_2	.27	.57	1.13
N_2	.84	.27	.27

* Time limitations precluded completion of complete storage testing. Taste panel data is based on two levels of treatment and taste test after two months storage.

TABLE 17

STATISTICAL ANALYSIS OF TASTE PANEL DATA

PANCAKE (SECOND RUN)

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2	20°C.	9.35	1.895	2.365	3.499
	38°C.	6.33	1.895	2.365	3.499
-18	+20°C.	12.98	1.895	2.365	3.499
N_2	20°C.	12.98	1.895	2.365	3.499
	38°C.	12.98	1.895	2.365	3.499
-18	+20°C.	7.33	1.895	2.365	3.499

[1]Observed [2]Confidence

Source of Variation	DF	SS	MS
Treatments	2	.04	.02
Levels	1	.02	.02
Cells	5	.10	
Treatments x Levels	2	.04	.02
Within Subgroups	42	23.38	.56
Total	47	23.48	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.04	3.23
F-Ratio MS(T x L)/MS(Within) =	.04	4.08
F-Ratio MS(Levels)/MS(Within) =	.04	3.23

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2	20°C.	-2.05	1.895	2.365	3.499
	38°C.	-4.58	1.895	2.365	3.499
-18	+20°C.	0	1.895	2.365	3.499
N_2	20°C.	-1.43	1.895	2.365	3.499
	38°C.	-2.38	1.895	2.365	3.499
-18	+20°C.	-2.38	1.895	2.365	3.499

Source of Variation	DF	SS	MS
Treatments	2	1.29	.65
Levels	1	.33	.33
Cells	5	2.92	
Treatments x Levels	2	1.29	.65
Within Subgroups	42	17.00	.40
Total	47	19.92	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	1.60	3.23
F-Ratio MS(T x L)/MS(Within) =	1.60	4.08
F-Ratio MS(Levels)/MS(Within) =	.82	3.23

TABLE 18

TASTE PANEL DATA

TOAST

Means of Scores

Preference

	-18° C.	20° C.	38° C.
O_2	2.00	1.88	1.50
N_2	1.75	1.63	1.75
T	2.13	1.25	1.25

Difference

	-18° C.	20° C.	38° C.
O_2	2.38	2.38	2.75
N_2	2.88	2.13	2.50
T	2.63	2.50	2.50

Variance in Scores

Preference

	-18° C.	20° C.	38° C.
O_2	.57	.70	.57
N_2	1.07	.27	.79
T	.98	.21	.21

Difference

	-18° C.	20° C.	38° C.
O_2	.84	1.13	.50
N_2	.70	.98	1.14
T	.55	.86	.86

TABLE 19

STATISTICAL ANALYSIS OF TASTE PANEL DATA

TOAST

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2 -18	20° C.	-0.42	±1.895	±2.365	±3.499
	38° C.	-1.87	1.895	2.365	3.499
	+20 °C	0.00	1.895	2.365	3.499
N_2 -18	20° C	-2.05	1.895	2.365	3.499
	38° C	-0.80	1.895	2.365	3.499
	+20 °C	-0.68	1.895	2.365	3.499
Tenox -18	20° C	-4.58	1.895	2.365	3.499
	38° C.	-4.58	1.895	2.365	3.499
	+20 °C	0.36	1.895	2.365	3.499

[1]observed [2]confidence

Source of variation	DF	SS	MS
Treatments	2	2.86	1.43
Levels	2	.78	.39
Cells	(8)	(6.03)	
Treatments x levels	4	2.39	.60
Within subgroups	63	37.63	.60
Total	71	43.65	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	2.40	3.15
F-Ratio MS(T x L)/MS(Within) =	1.00	2.53
F-Ratio MS(Levels)/MS(Within) =	.65	3.15

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2 -18	20° C	6.33	±1.895	±2.365	±2.998
	38° C	11.00	1.895	2.365	2.998
	+20 °C	7.33	1.895	2.365	2.998
N_2 -18	20° C	6.06	1.895	2.365	2.998
	38° C	6.61	1.895	2.365	2.998
	+20 °C	9.74	1.895	2.365	2.998
Tenox -18	20° C	7.64	1.895	2.365	2.998
	38° C	7.64	1.895	2.365	2.998
	+20 °C	9.98	1.895	2.365	2.998

Source of variation	DF	SS	MS
Treatments	2	1.19	.60
Levels	2	.03	.01
Cells	(8)	(3.11)	
Treatments x levels	4	1.90	.47
Within subgroups	63	52.88	.84
Total	71	55.99	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.71	3.15
F-Ratio MS(T x L)/MS(Within) =	.56	2.53
F-Ratio MS(Levels)/MS(Within) =	.02	3.15

TABLE 20

TASTE PANEL DATA

PUFFED RICE

Means of Scores

Preference

	-18° C.	20° C.	38° C.
O_2	1.88	1.88	2.00
N_2	1.00	1.63	1.63
T	1.75	1.50	1.75

Difference

	-18° C.	20° C.	38° C.
O_2	1.50	1.50	1.38
N_2	2.25	2.25	2.13
T	2.00	1.88	1.50

Variance in Scores

Preference

	-18° C.	20° C.	38° C.
O_2	.41	.41	.29
N_2	.00	.55	.55
T	.50	.29	.21

Difference

	-18° C.	20° C.	38° C.
O_2	1.14	.86	.84
N_2	.79	1.07	.98
T	.57	1.55	.86

TABLE 21

STATISTICAL ANALYSIS OF TASTE PANEL DATA

PUFFED RICE

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
	20° C.	-0.55	±1.895	±2.365	±3.499
O_2	38° C.	0.00	1.895	2.365	3.499
-18	+20 °C	-0.55	1.895	2.365	3.499
	20° C	-1.43	1.895	2.365	3.499
N_2	38° C	-1.43	1.895	2.365	3.499
-18	+20 °C	0.00	1.895	2.365	3.499
	20° C	-2.65	1.895	2.365	3.499
Tenox	38° C.	-1.53	1.895	2.365	3.499
-18	+20 °C	-1.00	1.895	2.365	3.499

[1]observed [2]confidence

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
	20° C	4.58	±1.895	±2.365	±2.998
O_2	38° C	4.25	1.895	2.365	2.998
-18	+20 °C	3.97	1.895	2.365	2.998
	20° C	6.15	1.895	2.365	2.998
N_2	38° C	6.06	1.895	2.365	2.998
-18	+20 °C	7.18	1.895	2.365	2.998
	20° C	4.25	1.895	2.365	2.998
Tenox	38° C	4.58	1.895	2.365	2.998
-18	+20 °C	7.48	1.895	2.365	2.998

Source of variation	DF	SS	MS
Treatments	2	.75	.38
Levels	2	3.00	1.50
Cells	(8)	(5.50)	
Treatments x levels	4	1.75	.44
Within subgroups	63	22.50	.36
Total	71	28.00	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	1.05	3.15
F-Ratio MS(T x L)/MS(Within) =	1.23	2.53
F-Ratio MS(Levels)/MS(Within) =	4.20	3.15

Source of variation	DF	SS	MS
Treatments	2	.86	.43
Levels	2	6.78	3.39
Cells	(8)	(8.03)	
Treatments x levels	4	.39	.10
Within subgroups	63	60.62	.96
Total	71	68.65	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.45	3.15
F-Ratio MS(T x L)/MS(Within) =	.10	2.53
F-Ratio MS(Levels)/MS(Within) =	3.52	3.15

TABLE 22

TASTE PANEL DATA

MACARONI

Means of Scores

Preference

	-18° C.	20° C.	38° C.
O_2	1.75	1.50	1.88
N_2	1.38	1.75	1.75
T	1.88	1.88	1.88

Difference

	-18° C.	20° C.	38° C.
O_2	1.63	1.25	1.50
N_2	1.50	1.25	1.38
T	1.25	1.38	1.13

Variance in Scores

Preference

	-18° C.	20° C.	38° C.
O_2	.50	.29	.41
N_2	.27	.21	.21
T	.41	.41	.41

Difference

	-18° C.	20° C.	38° C.
O_2	.55	1.07	1.71
N_2	.57	1.07	.27
T	1.36	1.41	.98

TABLE 23

STATISTICAL ANALYSIS OF TASTE PANEL DATA

MACARONI

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2	20° C.	-2.65	±1.895	±2.365	±3.499
	38° C.	-0.55	1.895	2.365	3.499
-18	+20 °C	-1.00	1.895	2.365	3.499
N_2	20° C	-1.53	1.895	2.365	3.499
	38° C	-1.53	1.895	2.365	3.499
-18	+20 °C	-3.42	1.895	2.365	3.499
Tenox	20° C.	-0.55	1.895	2.365	3.499
	38° C.	-0.55	1.895	2.365	3.499
-18	+20 °C	-0.55	1.895	2.365	3.499

[1]observed [2]confidence

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2	20° C	3.42	±1.895	±2.365	±2.998
	38° C	3.24	1.895	2.365	2.998
-18	+20 °C	6.18	1.895	2.365	2.998
N_2	20° C	3.42	1.895	2.365	2.998
	38° C	7.51	1.895	2.365	2.998
-18	+20 °C	5.61	1.895	2.365	2.998
Tenox	20° C	3.27	1.895	2.365	2.998
	38° C	3.21	1.895	2.365	2.998
-18	+20 °C	3.03	1.895	2.365	2.998

Source of variation	DF	SS	MS
Treatments	2	.36	.18
Levels	2	.78	.39
Cells	(8)	(2.11)	
Treatments x levels	4	.97	.24
Within subgroups	63	21.88	.35
Total	71	23.99	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.52	3.15
F-Ratio MS(T x L)/MS(Within) =	.70	2.53
F-Ratio MS(Levels)/MS(Within) =	1.12	3.15

Source of variation	DF	SS	MS
Treatments	2	.36	.18
Levels	2	.53	.26
Cells	(8)	(1.61)	
Treatments x levels	4	.72	.18
Within subgroups	63	63.00	1.00
Total	71	64.61	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.18	3.15
F-Ratio MS(T x L)/MS(Within) =	.18	2.53
F-Ratio MS(Levels)/MS(Within) =	.26	3.15

TABLE 24

TASTE PANEL DATA

CHICKEN

Means of Scores

Preference

	-18° C.	20° C.	38° C.
O_2	1.88	2.00	2.00
N_2	2.13	2.25	2.13
T	1.25	1.38	1.38

Difference

	-18° C.	20° C.	38° C.
O_2	1.75	2.00	2.00
N_2	1.13	.88	1.75
T	2.50	2.63	2.50

Variance in Scores

Preference

	-18° C.	20° C.	38° C.
O_2	.70	.57	.57
N_2	.13	.21	.70
T	.21	.55	.55

Difference

	-18° C.	20° C.	38° C.
O_2	1.93	1.14	1.14
N_2	.70	.70	1.93
T	1.43	1.13	2.00

CHICKEN - DRY

Sample	Storage Conditions	Preference		Difference	
		Means	Variance	Means	Variance
A	N_2 20° C.	1.5	0.5714	2.0	1.428
B	Tenox 38° C.	1.375	0.5533	2.625	1.695

TABLE 25

STATISTICAL ANALYSIS OF TASTE PANEL DATA

REHYDRATED CHICKEN

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
	20° C.	0.00	±1.895	±2.365	±3.499
O2	38° C.	0.00	1.895	2.365	3.499
-18	+20 °C	-0.42	1.895	2.365	3.499
	20° C	1.53	1.895	2.365	3.499
N_2	38° C	0.42	1.895	2.365	3.499
-18	+20 °C	1.00	1.895	2.365	3.499
	20° C	-2.38	1.895	2.365	3.499
Tenox	38° C.	-2.38	1.895	2.365	3.499
-18	+20 °C	-4.58	1.895	2.365	3.499

[1]observed [2]confidence

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
	20° C	5.29	±1.895	±2.365	±2.998
O_2	38° C	5.29	1.895	2.365	2.998
-18	+20 °C	3.56	1.895	2.365	2.998
	20° C	2.97	1.895	2.365	2.998
N_2	38° C	3.56	1.895	2.365	2.998
-18	+20 °C	3.81	1.895	2.365	2.998
	20° C	7.00	1.895	2.365	2.998
Tenox	38° C	5.00	1.895	2.365	2.998
-18	+20 °C	5.92	1.895	2.365	2.998

Source of variation	DF	SS	MS
Treatments	2	.19	.10
Levels	2	9.03	4.51
Cells	(8)	(9.28)	
Treatments x levels	4	.06	.01
Within subgroups	63	29.37	.47
Total	71	38.65	

Source of variation	DF	SS	MS
Treatments	2	1.19	.60
Levels	2	20.03	10.01
Cells	(8)	(23.69)	
Treatments x levels	4	2.47	.62
Within subgroups	63	84.63	1.34
Total	71	108.32	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.21	3.15
F-Ratio MS(T x L)/MS(Within) =	.03	2.53
F-Ratio MS(Levels)/MS(Within) =	9.68	3.15

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.44	3.15
F-Ratio MS(T x L)/MS(Within) =	.46	2.53
F-Ratio MS(Levels)/MS(Within) =	7.42	3.15

CHICKEN - DRY

Preference

t(obs)*	90% conf	95% conf	99% conf
0.37)	1.761	2.145	3.012

Difference

t(obs)*	90% conf	95% conf	99% conf
-1.	1.761	2.145	3.012

TABLE 26

TASTE PANEL DATA

BEEF (REHYDRATED)

Means of Scores

Preference

	-18° C.	20° C.	38° C.
O_2	1.75	1.75	2.38
N_2	1.75	2.25	1.50
T	1.63	2.00	1.75

Difference

	-18° C.	20° C.	38° C.
O_2	2.00	1.88	2.25
N_2	2.75	1.63	1.63
T	2.75	2.25	1.50

Variance in Scores

Preference

	-18° C.	20° C.	38° C.
O_2	.50	.50	.55
N_2	.79	.21	.29
T	.84	.86	.21

Difference

	-18° C.	20° C.	38° C.
O_2	1.14	1.27	.50
N_2	1.36	.84	1.98
T	1.07	.50	.57

BEEF - DRY

Sample	Storage Conditions	Preference Means	Preference Variance	Difference Means	Difference Variance
A	O_2 38° C.	2.75	0.4998	2.62	0.2678
B	O_2 Tenox -18 +20 °C.	1.875	0.6961	2.0	1.142

TABLE 27

STATISTICAL ANALYSIS OF TASTE PANEL DATA

REHYDRATED BEEF

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
	20° C.	-1.00	±1.895	±2.365	±3.499
O_2	38° C.	1.43	1.895	2.365	3.499
-18	+20 °C	-1.00	1.895	2.365	3.499
	20° C	1.53	1.895	2.365	3.499
N_2	38° C	-2.65	1.895	2.365	3.499
-18	+20 °C	-0.80	1.895	2.365	3.499
	20° C	0.00	1.895	2.365	3.499
Tenox	38° C.	-1.53	1.895	2.365	3.499
-18	+20 °C	-1.16	1.895	2.365	3.499

[1]observed [2]confidence

Source of variation	DF	SS	MS
Treatments	2	1.03	.51
Levels	2	.36	.18
Cells	(8)	(5.36)	
Treatments x levels	4	3.97	.99
Within subgroups	63	33.25	.53
Total	71	38.61	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.97	3.15
F-Ratio MS(T x L)/MS(Within) =	1.88	2.53
F-Ratio MS(Levels)/MS(Within) =	.34	3.15

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
	20° C	4.71		±2.365	±2.998
O_2	38° C	9.00	1.895	2.365	2.998
-18	+20 °C	5.29	1.895	2.365	2.998
	20° C	5.02	1.895	2.365	2.998
N_2	38° C	3.26	1.895	2.365	2.998
-18	+20 °C	6.68	1.895	2.365	2.998
	20° C	9.00	1.895	2.365	2.998
Tenox	38° C	5.61	1.895	2.365	2.998
-18	+20 °C	7.51	1.895	2.365	2.998

Source of variation	DF	SS	MS
Treatments	2	6.85	3.43
Levels	2	.36	.18
Cells	(8)	(14.03)	
Treatments x levels	4	6.81	1.70
Within subgroups	63	64.63	1.03
Total	71	78.65	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	3.34	3.15
F-Ratio MS(T x L)/MS(Within) =	1.66	2.53
F-Ratio MS(Levels)/MS(Within) =	.18	3.15

BEEF - DRY

Preference

t(obs)*	90% conf	95% conf	99% conf
2.272	1.761	2.145	3.012

Difference

t(obs)*	90% conf	95% conf	99% conf
1.493	1.761	2.145	3.012

* Compared two mean values of Samples A and B, using t test

TABLE 28

TASTE PANEL DATA

SHRIMP

Means of Scores

Preference

	-18° C.	20° C.	38° C.
O_2	1.38	1.38	1.38
N_2	2.00	2.13	1.88
T	2.00	1.50	1.63

Difference

	-18° C.	20° C.	38° C.
O_2	2.13	2.25	2.63
N_2	1.50	2.13	1.50
T	2.00	2.00	2.75

Variance in Scores

Preference

	-18° C.	20° C.	38° C.
O_2	.27	.27	.27
N_2	.57	.70	.41
T	.57	.29	.84

Difference

	-18° C.	20° C.	38° C.
O_2	.70	1.64	.27
N_2	.86	.70	.86
T	.57	1.14	.21

SHRIMP - DRY

Sample	Storage Conditions	Preference Means	Preference Variance	Difference Means	Difference Variance
A	N_2 20° C.	1.75	0.4997	2.25	1.07
B	O_2 20° C.	2.0	0.8571	1.875	1.553

TABLE 29

STATISTICAL ANALYSIS OF TASTE PANEL DATA

REHYDRATED SHRIMP

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2	20° C.	-3.42	±1.895	±2.365	±3.499
	38° C.	-3.42	1.895	2.365	3.499
-18	+20 °C	-3.42	1.895	2.365	3.499
N_2	20° C	0.42	1.895	2.365	3.499
	38° C	-0.55	1.895	2.365	3.499
-18	+20 °C	0.00	1.895	2.365	3.499
Tenox	20° C	-2.65	1.895	2.365	3.499
	38° C.	-1.16	1.895	2.365	3.499
-18	+20 °C	0.00	1.895	2.365	3.499

[1]observed [2]confidence

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2	20° C	4.97	±1.895	±2.365	±2.998
	38° C	14.35	1.895	2.365	2.998
-18	+20 °C	7.20	1.895	2.365	2.998
N_2	20° C	7.20	1.895	2.365	2.998
	38° C	4.58	1.895	2.365	2.998
-18	+20 °C	4.58	1.895	2.365	2.998
Tenox	20° C	5.29	1.895	2.365	2.998
	38° C	16.80	1.895	2.365	2.998
-18	+20 °C	7.48	1.895	2.365	2.998

Source of variation	DF	SS	MS
Treatments	2	.36	.18
Levels	2	4.69	2.35
Cells	(8)	(6.03)	
Treatments x levels	4	.97	.24
Within subgroups	63	29.25	.46
Total	71	35.28	

Source of variation	DF	SS	MS
Treatments	2	2.11	1.06
Levels	2	5.53	2.76
Cells	(8)	(11.69)	
Treatments x levels	4	4.06	1.01
Within subgroups	63	48.63	.77
Total	71	60.32	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.39	3.15
F-Ratio MS(T x L)/MS(Within) =	.52	2.53
F-Ratio MS(Levels)/MS(Within) =	5.06	3.15

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	1.37	3.15
F-Ratio MS(T x L)/MS(Within) =	1.31	2.53
F-Ratio MS(Levels)/MS(Within) =	3.58	3.15

SHRIMP - DRY

Preference

t(obs)*	90% conf	95% conf	99% conf
-0.737	1.761	2.145	3.012

Difference

t(obs)*	90% conf	95% conf	99% conf
0.657	1.761	2.145	3.012

TABLE 30

TASTE PANEL DATA

PEAS (DRY)

Means of Scores

Preference

	-18°C.	20°C.	38°C.
O_2	1.63	1.50	1.63
N_2	1.63	2.00	1.88
T	1.88	1.75	1.50

Difference

	-18°C.	20°C.	38°C.
O_2	2.13	2.13	1.88
N_2	1.38	2.00	1.75
T	1.63	1.13	1.63

Variance In Scores

Preference

	-18°C.	20°C.	38°C.
0	.55	.57	.27
N_2	.27	.57	.70
T	.41	.50	.29

Difference

	-18°C.	20°C.	38°C.
O_2	.98	1.84	1.27
N_2	1.13	1.43	1.93
T	1.13	.70	1.13

PEAS (COOKED)

Means of Scores

Preference

	-18°C.	20°C.	38°C.
O_2	1.75	2.38	2.00
N_2	1.88	1.88	1.88
T	2.00	2.25	1.88

Difference

	-18°C.	20°C.	38°C.
O_2	1.63	1.63	1.63
N_2	1.75	2.13	1.38
T	1.88	1.63	2.00

Variance in Scores

Preference

	-18°C.	20°C.	38°C.
O_2	.21	.55	.57
N_2	.41	.41	.70
T	.57	.50	.41

Difference

	-18°C.	20°C.	38°C.
O_2	.84	1.13	.84
N_2	1.64	1.27	.84
T	.70	1.13	1.14

TABLE 31

STATISTICAL ANALYSIS OF TASTE PANEL DATA

DRY PEAS

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2 -18	20°C.	-1.87	±1.895	±2.365	±3.499
	38°C.	-2.05	1.895	2.365	3.499
	+20°C.	-1.43	1.895	2.365	3.499
N_2 -18	20°C.	0	1.895	2.365	3.499
	38°C.	- .42	1.895	2.365	3.499
	+20°C.	-2.05	1.895	2.365	3.499
Tenox -18	20°C.	-1.00	1.895	2.365	3.499
	38°C.	-2.65	1.895	2.365	3.499
	+20°C.	- .55	1.895	2.365	3.499

[1]Observed [2]Confidence

Source of Variation	DF	SS	MS
Treatments	2	.08	.04
Levels	2	.75	.38
Cells	8	2.00	
Treatments x Levels	4	1.17	.29
Within Subgroups	63	28.88	.46
Total	71	30.88	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.09	3.15
F-Ratio MS(T x L)/MS(Within) =	.64	2.53
F-Ratio MS(Levels)/MS(Within) =	.82	3.15

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2 -18	20°C.	4.43	±1.895	±2.365	±2.998
	38°C.	4.71	1.895	2.365	2.998
	+20°C.	6.06	1.895	2.365	2.998
N_2 -18	20°C.	4.73	1.895	2.365	2.998
	38°C.	3.56	1.895	2.365	2.998
	+20°C.	3.67	1.895	2.365	2.998
Tenox -18	20°C.	3.81	1.895	2.365	2.998
	38°C.	4.33	1.895	2.365	2.998
	+20°C.	4.33	1.895	2.365	2.998

Source of Variation	DF	SS	MS
Treatments	2	.03	.01
Levels	2	4.11	2.06
Cells	8	7.36	
Treatments x Levels	4	3.22	.81
Within Subgroups	63	80.63	1.28
Total	71	87.99	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.01	3.15
F-Ratio MS(T x L)/MS(Within) =	.63	2.53
F-Ratio MS(Levels)/MS(Within) =	1.61	3.15

TABLE 32

STATISTICAL ANALYSIS OF TASTE PANEL DATA

REHYDRATED PEAS

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2 -18	20°C.	1.43	±1.895	±2.365	±3.499
	38°C.	0	1.895	2.365	3.499
	+20°C.	-1.53	1.895	2.365	3.499
N_2 -18	20°C.	- .42	1.895	2.365	3.499
	38°C.	- .55	1.895	2.365	3.499
	+20°C.	- .55	1.895	2.365	3.499
Tenox -18	20°C.	1.00	1.895	2.365	3.499
	38°C.	- .55	1.895	2.365	3.499
	+20°C.	0	1.895	2.365	3.499

[1]Observed [2]Confidence

Source of Variation	DF	SS	MS
Treatments	2	1.19	.60
Levels	2	.44	.22
Cells	8	2.61	
Treatments x Levels	4	.97	.24
Within Subgroups	63	30.38	.48
Total	71	32.99	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	1.24	3.15
F-Ratio MS(T x L)/MS(Within) =	.50	2.53
F-Ratio MS(Levels)/MS(Within) =	.46	3.15

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2 -18	20°C.	4.33	±1.895	±2.365	±2.998
	38°C.	5.02	1.895	2.365	2.998
	+20°C.	5.02	1.895	2.365	2.998
N_2 -18	20°C.	5.34	1.895	2.365	2.998
	38°C.	4.25	1.895	2.365	2.998
	+20°C.	3.86	1.895	2.365	2.998
Tenox -18	20°C.	4.33	1.895	2.365	2.998
	38°C.	5.29	1.895	2.365	2.998
	+20°C.	6.35	1.895	2.365	2.998

Source of Variation	DF	SS	MS
Treatments	2	.19	.10
Levels	2	.53	.26
Cells	8	3.36	
Treatments x Levels	4	2.64	.66
Within Subgroups	63	66.63	1.06
Total	71	69.99	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.09	3.15
F-Ratio MS(T x L)/MS(Within) =	.62	2.53
F-Ratio MS(Levels)/MS(Within) =	.25	3.15

TABLE 33

TASTE PANEL DATA

ASPARAGUS (DRY)

Means of Scores

Preference

	-18°C.	20°C.	38°C.
O_2	2.13	1.50	2.00
N_2	1.75	1.75	1.88
T	1.75	1.63	2.00

Difference

	-18°C.	20°C.	38°C.
O_2	2.13	2.13	1.63
N_2	1.63	2.13	2.00
T	2.00	1.75	1.88

Variance In Scores

Preference

	-18°C.	20°C.	38°C.
0	.41	.29	.57
N_2	.50	.21	.70
T	.50	.27	.57

Difference

	-18°C.	20°C.	38°C.
O_2	.70	.70	1.13
N_2	1.13	.70	1.14
T	2.00	.50	.98

ASPARAGUS (COOKED)

Means of Scores

Preference

	-18°C.	20°C.	38°C.
O_2	1.25	1.38	1.13
N_2	1.50	1.50	1.13
T	1.50	1.63	1.38

Difference

	-18°C.	20°C.	38°C.
O_2	2.38	2.00	3.25
N_2	1.88	2.00	3.00
T	2.25	2.25	2.25

Variance in Scores

Preference

	-18°C.	20°C.	38°C.
O_2	.21	.27	.13
N_2	.29	.29	.13
T	.57	.55	.27

Difference

	-18°C.	20°C.	38°C.
O_2	.84	.50	1.43
N_2	1.55	.57	1.14
T	.50	.79	1.07

TABLE 34

STATISTICAL ANALYSIS OF TASTE PANEL DATA

DRY ASPARAGUS

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2	20°C.	-2.65	±1.895	±2.365	±3.499
	38°C.	0	1.895	2.365	3.499
-18	+20°C.	.55	1.895	2.365	3.499
N_2	20°C.	-1.53	1.895	2.365	3.499
	38°C.	-.42	1.895	2 365	3.499
-18	+20°C.	-1.00	1.895	2.365	3.499
Tenox	20°C.	-2.05	1.895	2.365	3.499
	38°C.	0	1.895	2.365	3.499
-18	+20°C.	-1.00	1.895	2.365	3.499

[1]Observed [2]Confidence

Source of Variation	DF	SS	MS
Treatments	2	1.44	.72
Levels	2	.11	.06
Cells	8	2.53	
Treatments x Levels	4	.97	.24
Within Subgroups	63	28.12	.45
Total	71	30.65	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	1.62	3.15
F-Ratio MS(T x L)/MS(Within) =	.54	2.53
F-Ratio MS(Levels)/MS(Within) =	.12	3.15

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2	20°C.	7.20	±1.895	±2.365	±2.998
	38°C.	4.33	1.895	2.365	2.998
-18	+20°C.	7.20	1.895	2.365	2.998
N_2	20°C.	7.20	1.895	2.365	2.998
	38°C.	5.29	1.895	2.365	2.998
-18	+20°C.	4.33	1.895	2.365	2.998
Tenox	20°C.	7.00	1.895	2.365	2.998
	38°C.	5.35	1.895	2.365	2.998
-18	+20°C.	4.00	1.895	2.365	2.998

Source of Variation	DF	SS	MS
Treatments	2	.33	.17
Levels	2	.08	.04
Cells	8	2.75	
Treatments x Levels	4	2.33	.58
Within Subgroups	63	62.75	1.00
Total	71	65.50	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.17	3.15
F-Ratio MS(T x L)/MS(Within) =	.59	2.53
F-Ratio MS(Levels)/MS(Within) =	.04	3.15

TABLE 35

STATISTICAL ANALYSIS OF TASTE PANEL DATA

REHYDRATED ASPARAGUS

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2 -18	20°C.	-3.42	±1.895	±2.365	±3.499
	38°C.	-7.00	1.895	2.365	3.499
	+20°C.	-4.58	1.895	2.365	3.499
N_2 -18	20°C.	-2.65	1.895	2.365	3.499
	38°C.	-7.00	1.895	2.365	3.499
	+20°C.	-2.65	1.895	2.365	3.499
Tenox -18	20°C.	-1.43	1.895	2.365	3.499
	38°C.	-3.42	1.895	2.365	3.499
	+20°C.	-1.87	1.895	2.365	3.499

[1]Observed [2]Confidence

Source of Variation	DF	SS	MS
Treatments	2	1.08	.54
Levels	2	.75	.38
Cells	8	2.00	
Treatments x Levels	4	.17	.04
Within Subgroups	63	18.88	.30
Total	71	20.88	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	1.81	3.15
F-Ratio MS(T x L)/MS(Within) =	.14	2.53
F-Ratio MS(Levels)/MS(Within) =	1.25	3.15

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2 -18	20°C.	4.73	±1.895	±2.365	±2.998
	38°C.	13.00	1.895	2.365	2.998
	+20°C.	7.33	1.895	2.365	2.998
N_2 -18	20°C.	7.48	1.895	2.365	2.998
	38°C.	7.94	1.895	2.365	2.998
	+20°C.	4.25	1.895	2.365	2.998
Tenox -18	20°C.	7.18	1.895	2.365	2.998
	38°C.	6.15	1.895	2.365	2.998
	+20°C.	9.00	1.895	2.365	2.998

Source of Variation	DF	SS	MS
Treatments	3	108.46	36.15
Levels	2	.90	.45
Cells	11	114.21	
Treatments x Levels	6	4.85	.81
Within Subgroups	84	58.75	.70
Total	95	172.96	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	51.69	3.15
F-Ratio MS(T x L)/MS(Within) =	1.16	2.53
F-Ratio MS(Levels)/MS(Within) =	.64	3.15

TABLE 36

TASTE PANEL DATA

STRAWBERRIES (DRY)

Means of Scores

Preference

	-18°C.	20°C.	38°C.
O_2	2.13	2.25	2.13
N_2	1.75	1.75	1.25
T	1.88	1.88	1.88

Difference

	-18°C.	20°C.	38°C.
O_2	1.88	1.75	2.13
N_2	1.50	1.88	2.25
T	1.63	2.13	2.13

Variance in Scores

Preference

	-18°C.	20°C.	38°C.
O_2	.98	.50	.70
N_2	.21	.21	.21
T	.70	.70	.70

Difference

	-18°C.	20°C.	38°C.
O_2	.41	1.07	.70
N_2	.29	1.27	1.07
T	1.41	1.84	.98

TABLE 37

STATISTICAL ANALYSIS OF TASTE PANEL DATA

STRAWBERRIES

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2 -18	20°C.	1.00	±1.895	±2.365	±3.499
	38°C.	.42	1.895	2.365	3.499
	+20°C.	.36	1.895	2.365	3.499
N_2 -18	20°C.	-1.53	1.895	2.365	3.499
	38°C.	-4.58	1.895	2.365	3.499
	+20°C.	-1.53	1.895	2.365	3.499
Tenox -18	20°C.	- .42	1.895	2.365	3.499
	38°C.	- .42	1.895	2.365	3.499
	+20°C.	- .42	1.895	2.365	3.499

[1]Observed [2]Confidence

Source of Variation	DF	SS	MS
Treatments	2	.58	.29
Levels	2	4.08	2.04
Cells	8	5.50	
Treatments x Levels	4	.83	.21
Within Subgroups	63	34.38	.55
Total	71	39 88	

Source		F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within)	=	.53	3.15
F-Ratio MS(T x L)/MS(Within)	=	.38	2.53
F-Ratio MS(Levels)/MS(Within)	=	3.74	3.15

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2 -18	20°C.	4.78	±1.895	±2.365	±2.998
	38°C.	7.20	1.895	2.365	2.998
	+20°C.	8.28	1.895	2.365	2.998
N_2 -18	20°C.	4.71	1.895	2.365	2.998
	38°C.	6.15	1.895	2.365	2.998
	+20°C.	7.94	1.895	2.365	2.998
Tenox -18	20°C.	4.43	1.895	2.365	2.998
	38°C.	6.06	1.895	2.365	2.998
	+20°C.	3.87	1.895	2.365	2.998

Source of Variation	DF	SS	MS
Treatments	2	3.00	1.50
Levels	2	.08	.04
Cells	8	4.25	
Treatments x Levels	4	1.17	.29
Within Subgroups	63	63.25	1.00
Total	71	67.50	

Source		F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within)	=	1.49	3.15
F-Ratio MS(T x L)/MS(Within)	=	.29	2.53
F-Ratio MS(Levels)/MS(Within)	=	.04	3.15

TABLE 38

TASTE PANEL DATA

APPLES (DRY)

Means of Scores

Preferance

	-18°C.	20°C.	38°C.
O_2	2.00	2.00	2.25
N_2	2.00	2.00	2.00
T	2.00	2.00	2.25

Difference

	-18°C.	20°C.	38°C.
O_2	1.50	1.63	1.88
N_2	1.88	1.50	2.13
T	1.88	1.88	2.00

Variance In Scores

Preference

	-18°C.	20°C.	38°C.
0	.57	.29	.50
N_2	.29	.29	.29
T	.57	.57	.50

Difference

	-18°C.	20°C.	38°C.
O_2	1.14	.84	.70
N_2	.98	.86	1.27
T	.70	.70	1.71

APPLES (COOKED)

Means of Scores

Preference

	-18°C.	20°C.	38°C.
O_2	1.50	1.75	2.25
N_2	1.75	2.25	1.63
T	2.38	1.63	1.38

Difference

	-18°C.	20°C.	38°C.
O_2	2.13	2.00	1.63
N_2	1.63	1.88	1.88
T	2.13	2.00	2.75

Variance in Scores

Preference

	-18°C.	20°C.	38°C.
O_2	.29	.21	.21
N_2	.21	.21	.55
T	.27	.27	.55

Difference

	-18°C.	20°C.	38°C.
C_2	.98	.29	1.41
N_2	1.13	.41	.98
T	.98	.57	.50

TABLE 39

STATISTICAL ANALYSIS OF TASTE PANEL DATA

DRY APPLES

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2 -18	20°C.	0	±1.895	±2.365	±3.499
	38°C.	1.00	1.895	2.365	3.499
	+20°C.	0	1.895	2.365	3.499
N_2 -18	20°C.	0	1.895	2.365	3.499
	38°C.	0	1.895	2.365	3.499
	+20°C.	0	1.895	2.365	3.499
Tenox -18	20°C.	0	1.895	2.365	3.499
	38°C.	1.00	1.895	2.365	3.499
	+20°C.	0	1.895	2.365	3.499

[1]Observed [2]Confidence

Source of Variation	DF	SS	MS
Treatments	2	.44	.22
Levels	2	.11	.06
Cells	8	.78	
Treatments x Levels	4	.22	.06
Within Subgroups	63	27.00	.43
Total	71	27.78	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.52	3.15
F-Ratio MS(T x L)/MS(Within) =	.13	2.53
F-Ratio MS(Levels)/MS(Within) =	.13	3.15

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2 -18	20°C.	5.02	±1.895	±2.365	±2.998
	38°C.	6.35	1.895	2.365	2.998
	+20°C.	3.97	1.895	2.365	2.998
N_2 -18	20°C.	4.58	1.895	2.365	2.998
	38°C.	5.34	1.895	2.365	2.998
	+20°C.	5.35	1.895	2.365	2.998
Tenox -18	20°C.	6.35	1.895	2.365	2.998
	38°C.	4.32	1.895	2.365	2.998
	+20°C.	6.35	1.895	2.365	2.998

Source of Variation	DF	SS	MS
Treatments	2	1.44	.72
Levels	2	.78	.39
Cells	8	3.03	
Treatments x Levels	4	.81	.20
Within Subgroups	63	62.25	.99
Total	71	65.28	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.73	3.15
F-Ratio MS(T x L)/MS(Within) =	.20	2.53
F-Ratio MS(Levels)/MS(Within) =	.39	3.15

TABLE 40

STATISTICAL ANALYSIS OF TASTE PANEL DATA

REHYDRATED APPLES

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2 -18	20°C. / 38°C.	-1.53	±1.895	±2.365	±3.499
	38°C. / +20°C.	1.53	1.895	2.365	3.499
N_2 -18	20°C. / 38°C.	-2.65	1.895	2.365	3.499
	38°C. / +20°C.	1.53	1.895	2.365	3.499
Tenox -18	20°C. / 38°C.	-1.43	1.895	2.365	3.499
	38°C. / +20°C.	-1.53	1.895	2.365	3.499
		-2.05	1.895	2.365	3.499
		-2.38	1.895	2.365	3.499
		2.05	1.895	2.365	3.499

[1]Observed [2]Confidence

Source of Variation	DF	SS	MS
Treatments	2	.25	.13
Levels	2	.08	.04
Cells	8	8.50	
Treatments x Levels	4	8.17	2.04
Within Subgroups	63	19.50	.31
Total	71	28.00	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.40	3.15
F-Ratio MS(T x L)/MS(Within) =	6.60	2.53
F-Ratio MS(Levels)/MS(Within) =	.13	3.15

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2 -18	20°C. / 38°C.	10.58	±1.895	±2.365	±2.998
	38°C. / +20°C.	3.87	1.895	2.365	2.998
N_2 -18	20°C. / 38°C.	6.06	1.895	2.365	2.998
	38°C. / +20°C.	8.28	1.895	2.365	2.998
Tenox -18	20°C. / 38°C.	5.35	1.895	2.365	2.998
	38°C. / +20°C.	4.33	1.895	2.365	2.998
		7.48	1.895	2.365	2.998
		11.00	1.895	2.365	2.998
		6.06	1.895	2.365	2.998

Source of Variation	DF	SS	MS
Treatments	2	.25	.13
Levels	2	3.25	1.63
Cells	8	7.25	
Treatments x Levels	4	3.75	.94
Within Subgroups	63	50.75	.81
Total	71	58.00	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.16	3.15
F-Ratio MS(T x L)/MS(Within) =	1.16	2.53
F-Ratio MS(Levels)/MS(Within) =	2.02	3.15

TABLE 41

TASTE PANEL DATA

COTTAGE CHEESE (DRY)

Means of Scores

Preference

	-18°C.	20°C.	38°C.
O_2	1.75	1.88	1.88
N_2	1.88	2.13	2.00
T	2.00	2.25	2.13

Difference

	-18°C.	20°C.	38°C.
O_2	1.75	2.13	2.13
N_2	1.50	2.00	1.75
T	1.88	2.00	2.25

Variance in Scores

Preference

	-18°C.	20°C.	38°C.
O_2	.50	.70	.70
N_2	.41	.70	.29
T	.86	.21	.70

Difference

	-18°C.	20°C.	38°C.
O_2	1.07	1.55	1.27
N_2	1.14	.86	.79
T	1.27	.86	1.07

TABLE 42

STATISTICAL ANALYSIS OF TASTE PANEL DATA

COTTAGE CHEESE

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2	20°C.	- .42	±1.895	±2.365	±3.499
	38°C.	- .42	1.895	2.365	3.499
-18	+20°C.	-1.00	1.895	2.365	3.499
N_2	20°C.	.42	1.895	2.365	3.499
	38°C.	0	1.895	2.365	3.499
-18	+20°C.	- .55	1.895	2.365	3.499
Tenox	20°C.	1.53	1.895	2.365	3.499
	38°C.	.42	1.895	2.365	3.499
-18	+20°C.	0	1.895	2.365	3.499

[1]Observed [2]Confidence

Source of Variation	DF	SS	MS
Treatments	2	.53	.26
Levels	2	1.03	.51
Cells	8	1.61	
Treatments x Levels	4	.06	.01
Within Subgroups	63	35.38	.56
Total	71	36.99	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.47	3.15
F-Ratio MS(T x L)/MS(Within) =	.02	2.53
F-Ratio MS(Levels)/MS(Within) =	.92	3.15

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2	20°C.	4.82	±1.895	±2.365	±2.998
	38°C.	5.34	1.895	2.365	2.998
-18	+20°C.	4.71	1.895	2.365	2.998
N_2	20°C.	6.11	1.895	2.365	2.998
	38°C.	5.58	1.895	2.365	2.998
-18	+20°C.	3.97	1.895	2.365	2.998
Tenox	20°C.	6.11	1.895	2.365	2.998
	38°C.	6.15	1.895	2.365	2.998
-18	+20°C.	4.71	1.895	2.365	2.998

Source of Variation	DF	SS	MS
Treatments	2	1.78	.89
Levels	2	1.19	.60
Cells	8	3.53	
Treatments x Levels	4	.56	.14
Within Subgroups	63	69.13	1.10
Total	71	72.65	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.81	3.15
F-Ratio MS(T x L)/MS(Within) =	.13	2.53
F-Ratio MS(Levels)/MS(Within) =	.54	3.15

TABLE 43

TASTE PANEL DATA

BEEF STEW (REHYDRATED)

Means of Scores

Preference

	-18°C.	20°C.	38°C.
O_2	2.50	2.38	1.63
N_2	2.50	2.50	1.88
T	2.25	2.13	1.88

Difference

	-18°C.	20°C.	38°C.
O_2	1.88	1.25	2.25
N_2	1.88	1.38	1.75
T	2.00	2.13	1.50

Variance in Scores

Preference

	-18°C.	20°C.	38°C.
O_2	.57	.27	.84
N_2	.29	.29	.70
T	.50	.41	.70

Difference

	-18°C.	20°C.	38°C.
O_2	1.84	.79	.50
N_2	.98	.55	.50
T	.29	.41	.86

TABLE 44

STATISTICAL ANALYSIS OF TASTE PANEL DATA

BEEF STEW

Preference

Storage Conditions		t(obs[1])	90% conf[2]	95% conf	99% conf
O_2 -18	20°C. +20°C.	2.05	±1.895	±2.365	±3.499
	38°C. +20°C.	-1.16	1.895	2.365	3.499
	20°C. +20°C.	1.87	1.895	2.365	3.499
N_2 -18	20°C. +20°C.	2.65	1.895	2.365	3.499
	38°C. +20°C.	- .42	1.895	2.365	3.499
	20°C. +20°C.	2.65	1.895	2.365	3.499
Tenox -18	20°C. +20°C.	.55	1.895	2.365	3.499
	38°C. +20°C.	- .42	1.895	2.365	3.499
	20°C. +20°C.	1.00	1.895	2.365	3.499

[1]Observed [2]Confidence

Source of Variation	DF	SS	MS
Treatments	2	5.53	2.76
Levels	2	.53	.26
Cells	8	6.78	
Treatments x Levels	4	.72	.18
Within Subgroups	63	31.88	.51
Total	71	38.65	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	5.46	3.15
F-Ratio MS(T x L)/MS(Within) =	.36	2.53
F-Ratio MS(Levels)/MS(Within) =	.52	3.15

Difference

Storage Conditions		t(obs)	95% conf	97.5% conf	99% conf
O_2 -18	20°C. +20°C.	3.99	±1.895	±2.365	±2.998
	38°C. +20°C.	9.00	1.895	2.365	2.998
	20°C. +20°C.	3.91	1.895	2.365	2.998
N_2 -18	20°C. +20°C.	5.23	1.895	2.365	2.998
	38°C. +20°C.	7.00	1.895	2.365	2.998
	20°C. +20°C.	5.35	1.895	2.365	2.998
Tenox -18	20°C. +20°C.	9.38	1.895	2.365	2.998
	38°C. +20°C.	4.58	1.895	2.365	2.998
	20°C. +20°C.	10.58	1.895	2.365	2.998

Source of Variation	DF	SS	MS
Treatments	2	1.44	.72
Levels	2	.53	.26
Cells	8	7.44	
Treatments x Levels	4	5.47	1.37
Within Subgroups	63	47.00	.75
Total	71	54.44	

Source	F(obs)	F (95%)
F-Ratio MS(Treat)/MS(Within) =	.97	3.15
F-Ratio MS(T x L)/MS(Within) =	1.83	2.53
F-Ratio MS(Levels)/MS(Within) =	.35	3.15

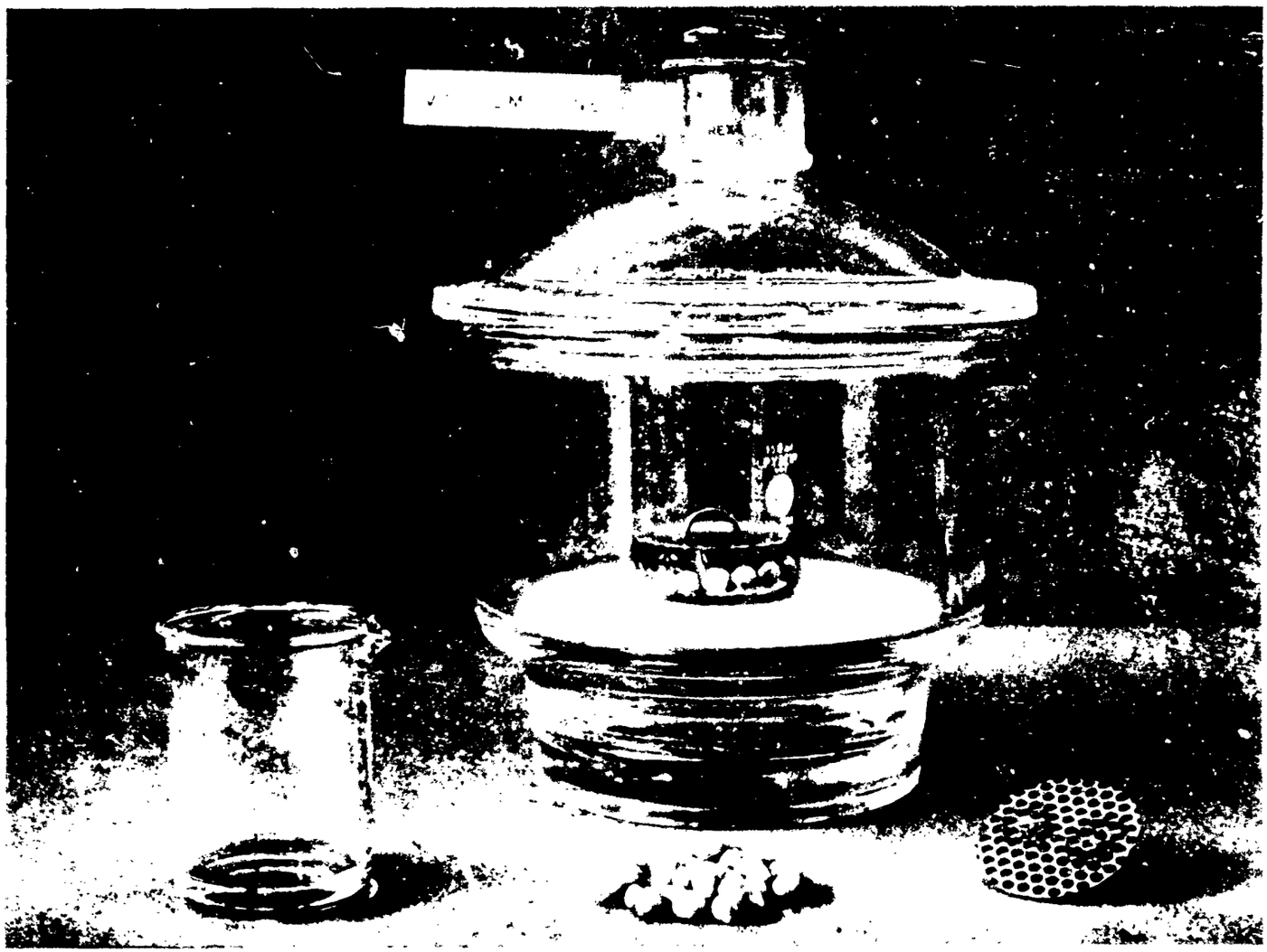


Figure 1 EQUIPMENT SETUP FOR VACUUM PENETRATION PROCEDURE

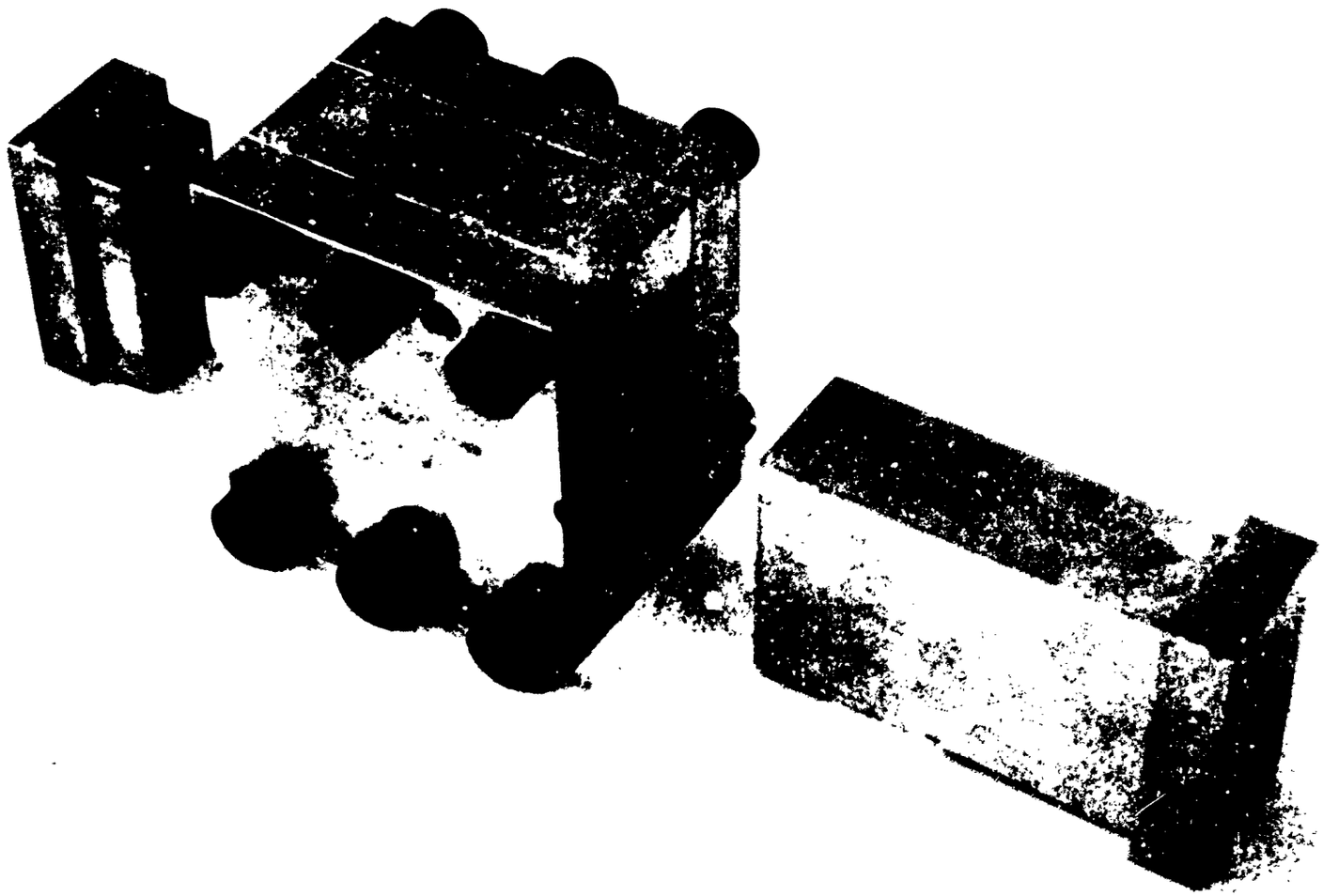


Figure 2 RECTANGULAR DIE USED FOR POSITIVE PRESSURE INFILTRATION

Figure 3 HAND PUMP FOR STUFFING MACARONI

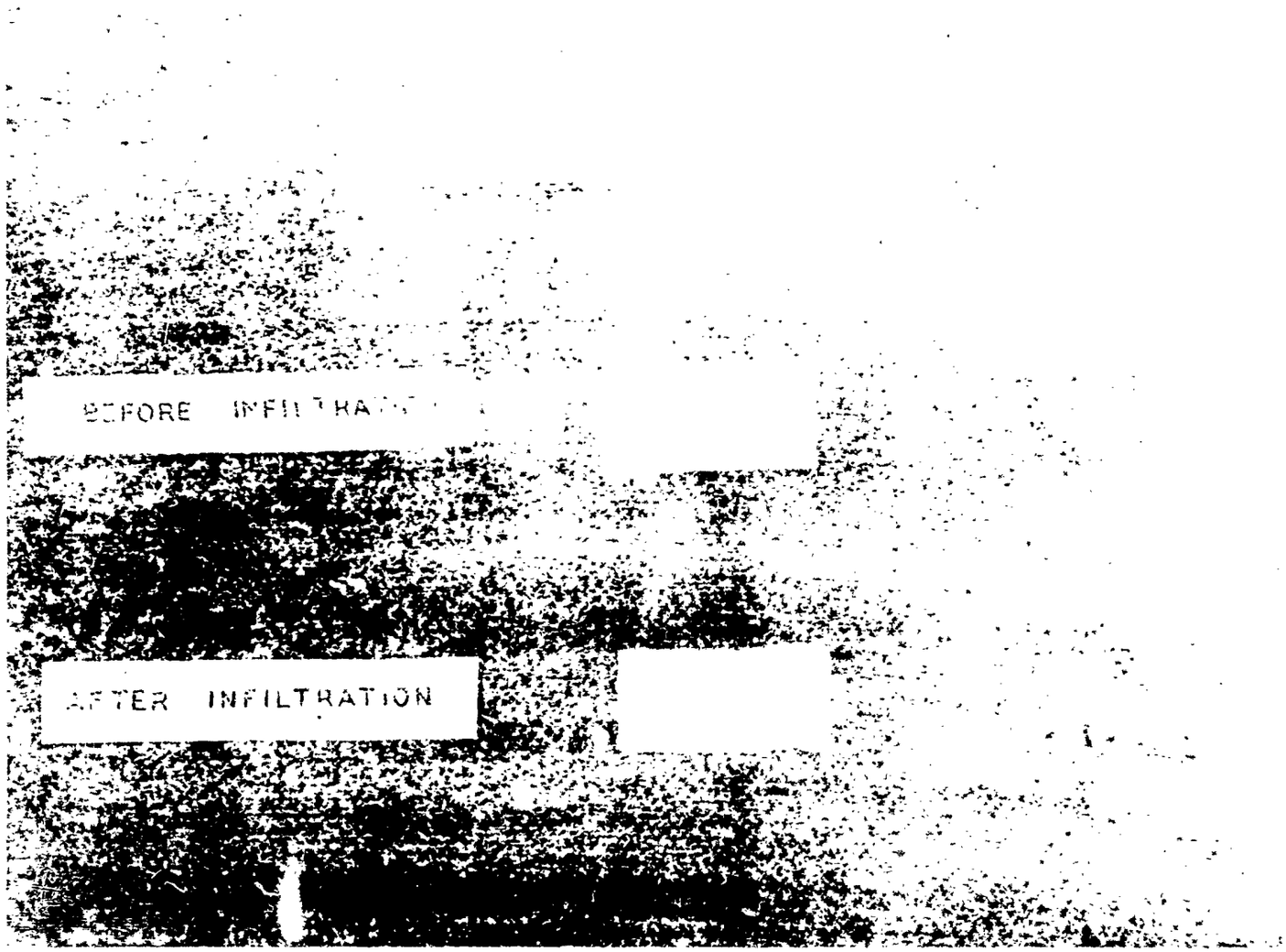


Figure 4 INFILTRATED POUND CAKE AND PANCAKE

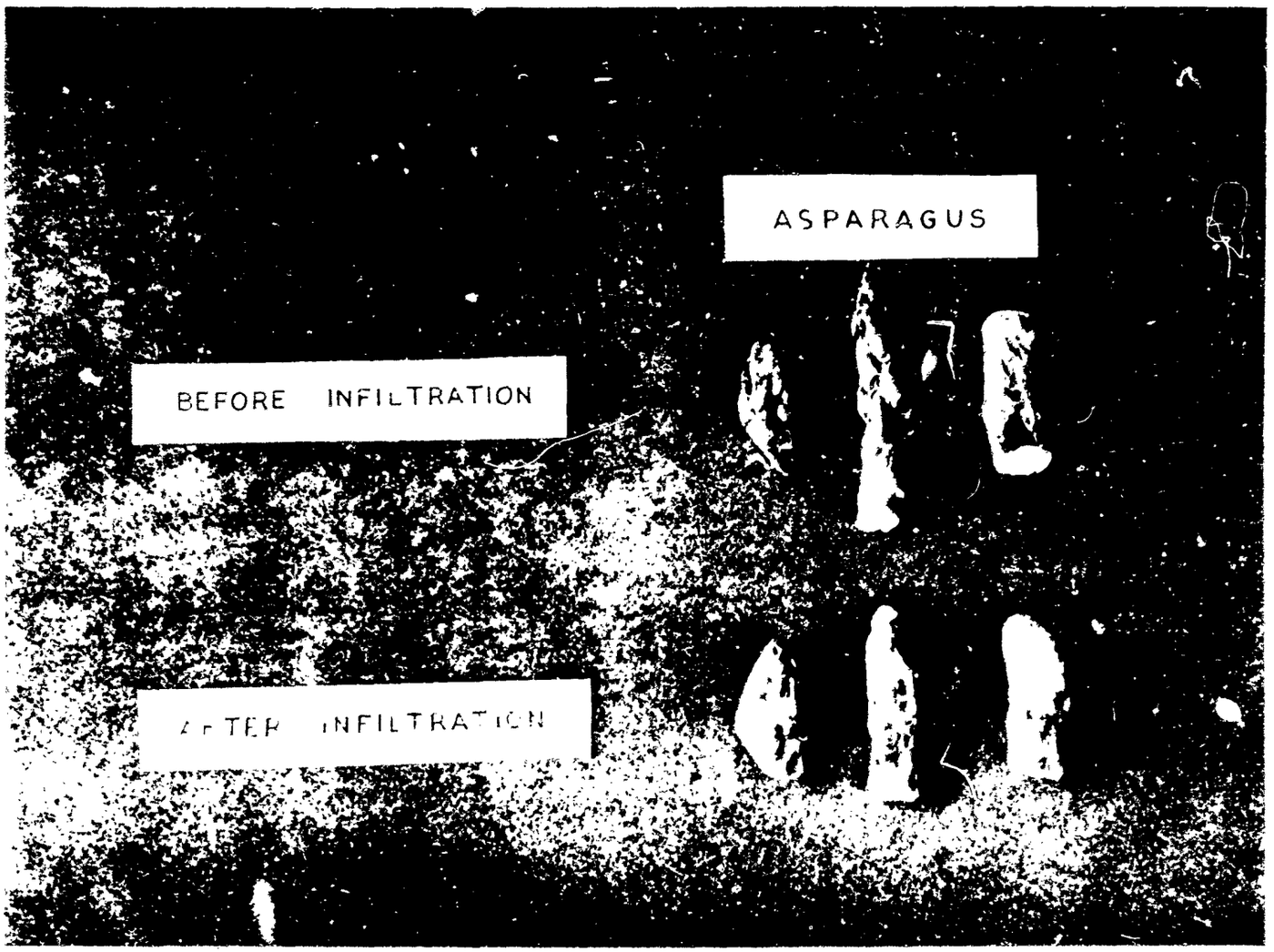


Figure 5 ASPARAGUS

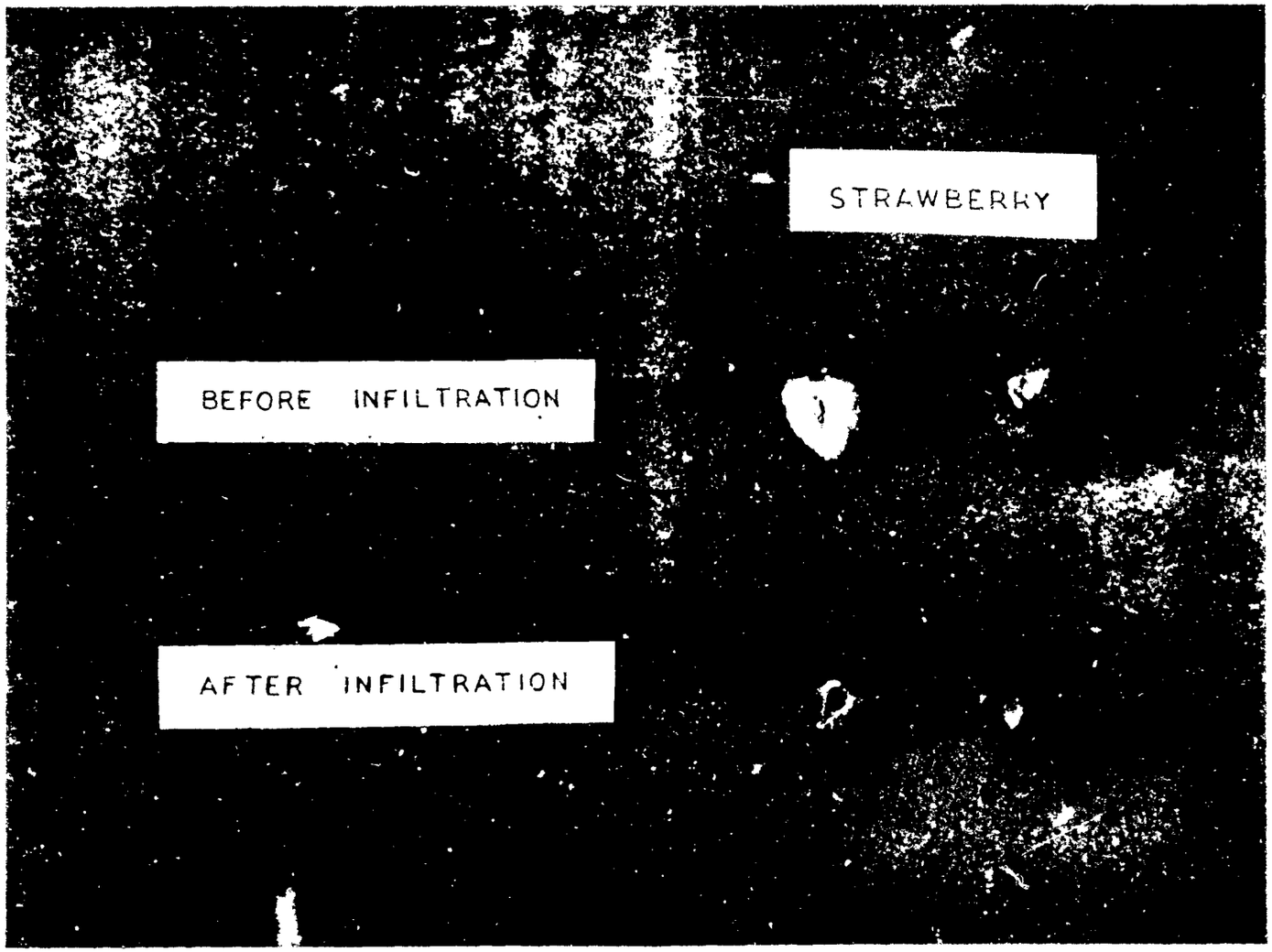


Figure 6 STRAWBERRY

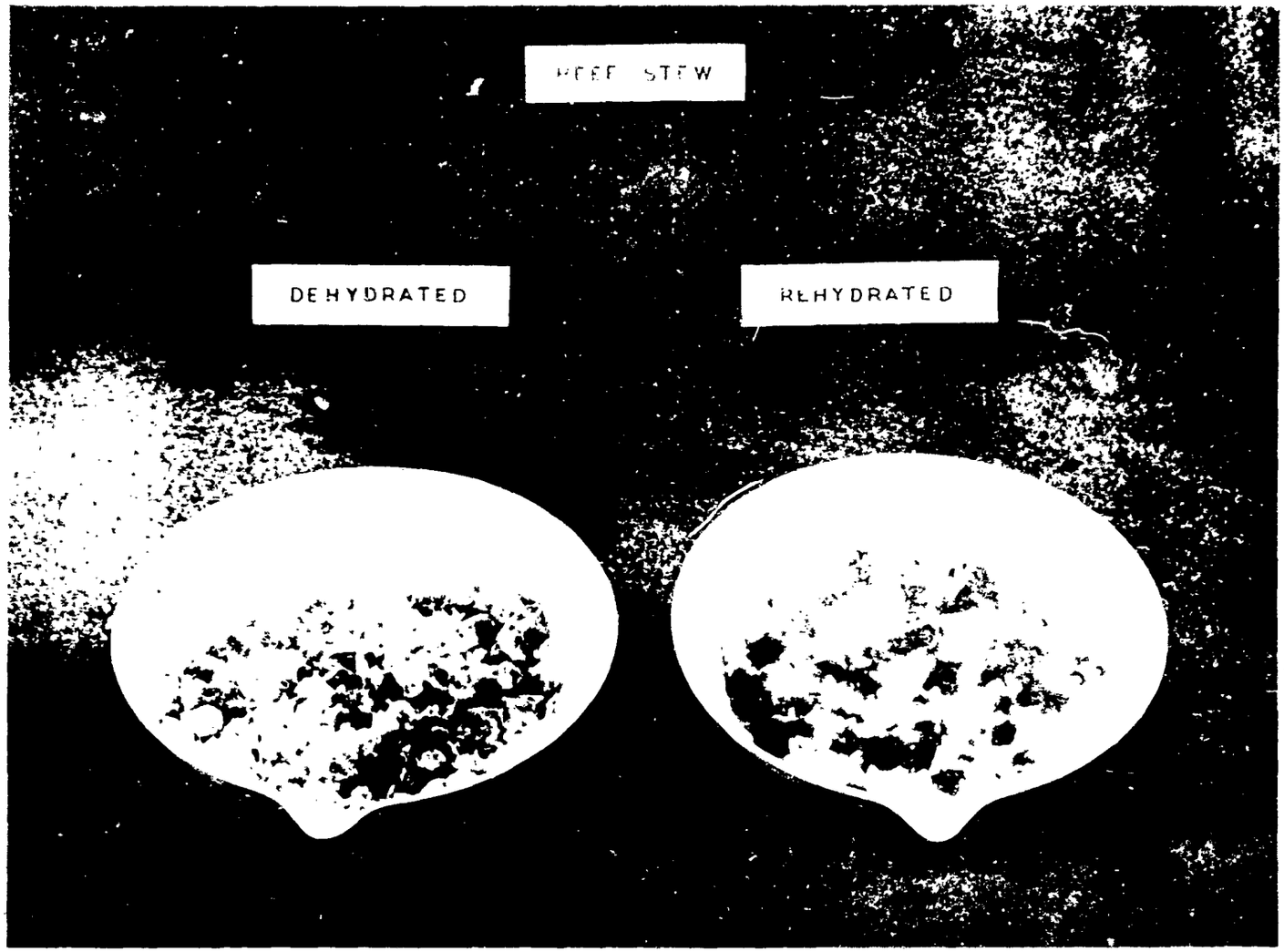


Figure 7 INFILTRATED BEEF STEW

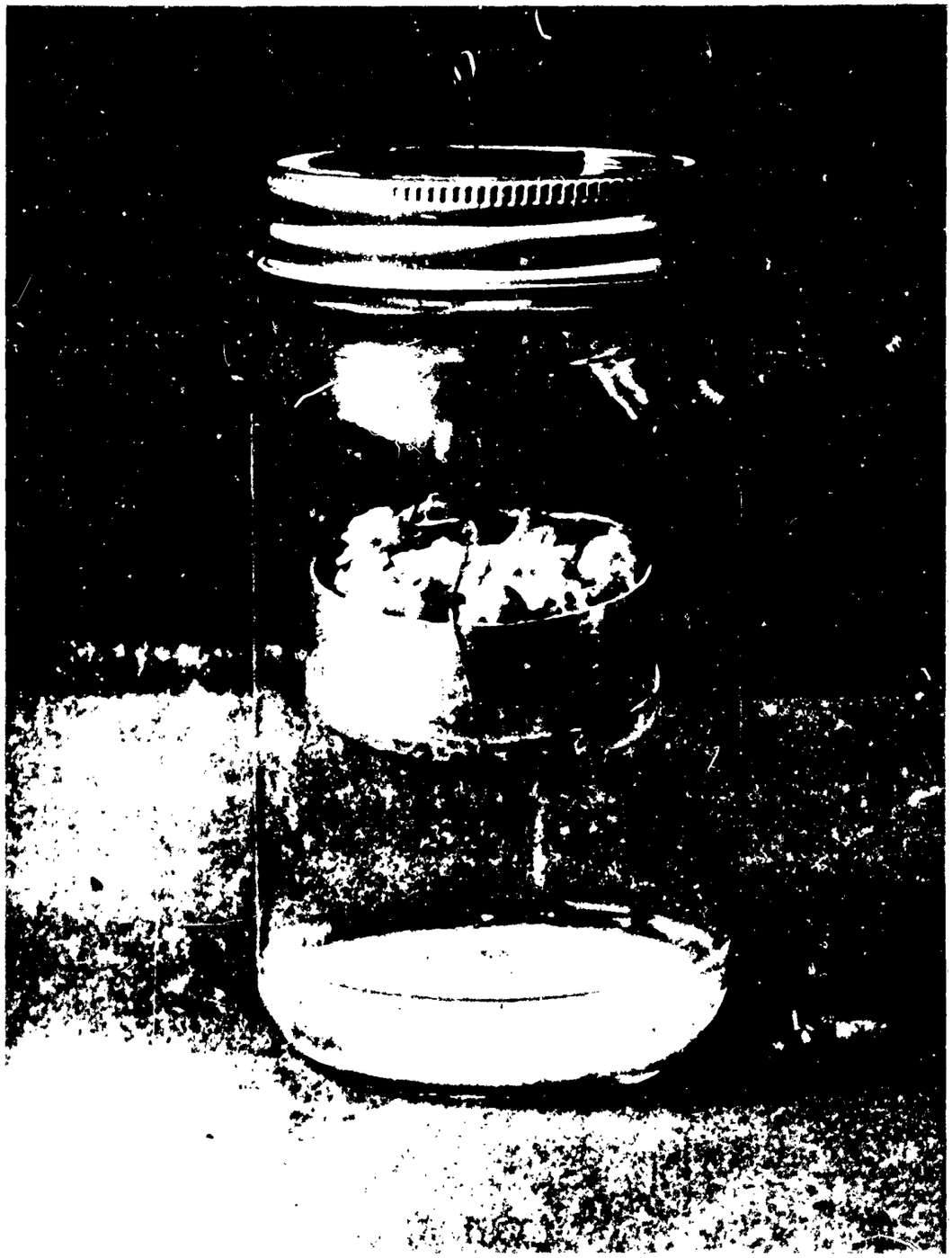


Figure 8 ASSEMBLED VIEW OF HUMIDITY JAR USED FOR DETERMINING EQUILIBRIUM MOISTURE CONTENT

Name _____ Product _____

Compare the flavor of each of the numbered samples with that of the reference sample "S", and indicate the relative difference and relative acceptance from sample "S" by checking the appropriate squares. DO NOT MARK BETWEEN SQUARES!

SAMPLE____

Difference		Preference	
Great	5☐	More Acceptable	3☐
Moderate	4☐		
Slight	3☐	Comparable	2☐
Very slight	2☐		
No difference	1☐	Less Acceptable	1☐

Comments

_____

_____

I

FIGURE 9

Sample Taste Ballot

SECTION II

Flow Sheet Diagrams and Design of Equipment for Producing 500 Kg/hr of Infiltrated Foods

I. INTRODUCTION

Contract No. DA 19-129-AMC-84(N) requires that a process flow sheet be prepared for the fourteen foods listed. The flow sheets are required to show materials, quantities, and equipment necessary to produce 500 Kg/hr (1102 lbs/hr) of food product. A more detailed investigation and definition is required for the process equipment necessary in processing the above production on one product within each of the following groups:

Group 1. Freeze dried beef, chicken, shrimp, and cottage cheese.
Group 2. Freeze dried peas, asparagus, strawberries and apples.
Group 3. Puffed rice, zwieback toast, pound cake, and pancakes.
Group 4. Macaroni and freeze dried beef stew.

For the more detailed investigation, shrimp was chosen from Group 1, asparagus from Group 2, pound cake from Group 3, and beef stew from Group 4.

II. METHODS OF PROCESSING

The freeze dried beef, chicken, shrimp, peas, asparagus, and beef stew are processed by the vacuum release system. Freeze dried cottage cheese is also processed by the vacuum release system, but with a prior pressing operation to form the cheese into a solid bar. Freeze dried strawberries, apples, and puffed rice are processed by the vacuum release system and subsequently coated. Zwieback toast, pound cake, and pancake are processed by the positive pressure method. Macaroni must be filled by mechanical injection.

A. Vacuum Release

The vacuum release system requires that the food be submerged in the filler emulsion within a container. The container is then placed in a vacuum chamber and a vacuum drawn. The vacuum is then quickly released when the emulsion starts to bubble. Breaking the vacuum causes the emulsion to penetrate the food. For best penetration, 6 cycles of vacuum and release are required.

B. Positive Pressure

Impregnation of food by the positive pressure system is accomplished by placing the food sample in a die set. The emulsion is placed on top of the food, and the mating die is used to press the emulsion into the food under pressure. The pressure required is approximately 100 psi and is held for about 60 seconds to permit the escape of air entrapped in the food.

C. Mechanical Injection

A mechanical injection system is needed to fill the void in macaroni. The machine to accomplish this on a large scale would be necessarily complex and costly, but nevertheless feasible.

III. PROCESS FLOW

The process flow diagrams, showing materials, quantities of materials, and equipment necessary to produce 1102 lbs/hr (500 Kg/hr) of product, are shown in Figures 1 through 14. Table 1 shows the method used in arriving at the quantities shown on the process flow diagram. The densities shown in Columns 1, 2, and 3 are given in Table 2 of the previous section. Columns 4 and 5 are based on the original density as being the percent of food in the final product and the weight gain as being the percent of filler in the final product. Columns 6 and 7 are the percentages shown in Columns 4 and 5, taken of 1102 lbs, which is the desired production per hour. The filler ingredients and their mixture ratios (Columns 8 and 9) are given in Table 5 of the previous section. Column 10 of Table 1 is the percentage shown in Column 9 of the weight flow established in Column 7. Flows of food shown in Column 6 and fillers shown in Column 10 are the flows shown in the process flow diagrams. These flows may be used to select the size and type of equipment needed to process the various ingredients. With proper correlation it is possible to select equipment so that more than one product may be processed with the same equipment. However, before any equipment could be selected the physicl characteristics pertinent to handling and proportioning the material must be considered.

IV. EQUIPMENT DESIGN PARAMETERS

In order to specify production facilities for the food products concerned here, it is necessary to formulate parameters and requirements to guide the plant design and equipment selection. The following must be considered along with the more general parameters:

A. The amount and type of labor required. This would determine the degree of automation needed to meet the production rates, and would be a prime consideration in the selection of equipment.

B. A more detailed specification is required concerning the number of different food products to be handled by the facility. This information is necessary in order to specify equipment which could be used for more than one ingredient or for more than one food product. A master flow sheet could then be formulated.

C. Requirements concerning exposure of the foods and ingredients to the atmosphere during storage, proportioning, filling, and handling must be determined in order to specify protective means. Protection from bacteria and moisture must be considered.

D. Means for increasing the capacity or increasing the variety of products must be considered.

E. The nature of the foods and filler ingredients to be processed must be studied to establish the handling means, proportioning techniques, and protective measures best suited to each particular ingredient in the product. Data needed would concern weight, nature of product (powder, liquid, slices, paste, etc.), size of pieces (if solid or granular), flowability, cohesive tendency, adhesive tendency, friability, and compaction problems.

F. Conditions relating to storage of the foods, filler ingredients, and final product must be determined (type of atmosphere, moisture, temperature, etc.) and data concerning shipping, receiving, and condition of product as received, must be established in order to provide adequate storage space and facilities.

G. The type of container for the final product must be established in order to select the proper packaging equipment.

H. A thorough investigation must be performed of available commercial equipment which would have to be designed.

V. EQUIPMENT SELECTION AND DESIGN

In order to satisfy the contract requirements as outlined in Section I, paragraph 1; that is, define the equipment needed to process the selected four foods, it is necessary to design a vacuum chamber for processing shrimp, asparagus, and beef stew and a press for processing pound cake. Capacity of both the vacuum chamber and press is to be 1102 lbs/hr of these foods.

It is felt that all or most of the other processing equipment needed is commercially available and can be accurately defined when the design parameters outlined in Section IV are known. A preliminary selection was made based upon known information about the particular task and physical characteristics of the material. This equipment appears on the flow sheets of the four foods (shrimp-Fig. 3, asparagus-Fig. 6, pound cake-Fig. 11, and beef stew-Fig. 14). No attempt is made to define the facility beyond this.

A. Vacuum Chamber. The vacuum chamber and its associated equipment are designed based upon laboratory test data, and the vacuum chamber shown in Figure 15 represents a scaled-up version of this equipment.

The vacuum chamber, vacuum pump, emulsion trays, and food baskets are sized according to the desired production, in this case 500 Kg/hr or 1102 lbs/hr. Assuming the chamber and vacuum pumping system is sized so that the required 28 inch Hg vacuum is drawn in four minutes, then the required 6 cycles would take 24 minutes. Alloting 6 minutes for loading and unloading the required processing time for one chamber load would be 30 minutes, giving two loads per hour. The vacuum chamber must then be large enough to produce 551 lbs of product per load. The density of the food then determines the final size. Table 1 gives the densities of the various foods and Table 2 gives the associated volumes needed for the required production. If more than one product is to be

processed in the same chamber then the chamber should be sized for the food with the greatest volume per pound.

Table 2 shows that of the three foods concerned, i.e. shrimp, asparagus, and beef stew; asparagus has the greatest volume per pound, requiring 52,650 cu in/hr to obtain 1102 lbs of product per hour. The beef stew is not considered since it is made of four processed foods and it is assumed that these foods will be processed separately, stored, and then mixed at the proper weight ratio to obtain the desired production. The chamber (Figure 15) then in order to process asparagus at the required production rate should hold $\frac{52,650}{2}$ or approximately 26,400 cu in.

The food must be placed in baskets so as to be submerged in the filler material. A basket one inch deep was selected so that the food layer would be thin enough for good impregnation. The basket would be retained in a tray of emulsion with 1/2 inch emulsion depth on bottom and 1/2 inch on top of the food, thus requiring a tray about three inches deep. Allowing for adequate clearance, eight trays, 32 inches wide will fit in a four foot diameter chamber, which is a convenient size.

Length of tray = $\frac{26,400}{(1)(32)(8)}$ = 103 inches. For ease of handling, 16 trays 51.5 inches long are used. In order to facilitate loading and unloading the food trays in the vacuum chamber, a mobile cart is provided, running on rails which extend into the vacuum chamber. The shelves of the cart are in actuality heating plattens containing a circulating heating fluid which maintains the correct emulsion temperature during the penetration operation. The heating fluid lines are coupled to the shelf cart by flexible hoses after the cart is placed in the chamber. Before the cart is removed from the chamber, the heating fluid must be purged from the cart and stored, and the hoses disconnected. The heating fluid temperature can be maintained by a steam heat exchanger and the necessary temperature controls.

Loading the food in the basket, filling the trays with emulsion, and placing the food basket in the trays can be accomplished manually or by automatic loading and unloading equipment. The cart should move along tracks to the stations where each of these operations are performed.

Once the cart is placed in the chamber, the heading fluid hoses connected, and the chamber door closed, the 6 cycles of evacuation and release can be completely automatic by vacuum switches, motor operated valves, and electric timers.

B. Press. The design parameters for a press to force fillers into foods are established by laboratory tests and by contract No. DA 19-129-AMC-84(N). The laboratory testing equipment and test results are described in the earlier part of this report. These tests show that for good penetration the die pressure required is 100 psi and that the pressure should be maintained for 60 seconds. The above contract specifies the food sample size be 1" x 2" x 1/2" and that the production rate be 500 Kg/hr (1102 lbs/hr).

To determine the number of dies required to obtain this production, it is necessary to establish: (1) Density of product in lbs/cu in; (2) Weight of one bar of product; (3) Number of bars needed to weigh

1102 pounds; (4) Number of cycles obtainable per hour of each die; and (5) pounds of production per hour per die.

For pound cake, the selected food for the positive pressure system, the impregnated density is .88 gms/cc (Table 1) x $\frac{.0327}{.061 \times 16}$ = .032 lbs/cu in.

One bar of product 1 x 2 x .5 = 1 cu in, so one bar weighs .032 pounds. Bars needed to weigh 1102 lbs = $\frac{1102}{.032}$ = 34,375.

A machine capable of producing 34,375 bars per hour is the design goal. Assuming 5 seconds to load the food and emulsion into the die and 2 seconds to eject the product, establishes the cycle time for the die at 67 seconds; therefore, $\frac{3600}{67}$ = 53.73 cycles per hour per die. Pounds of product per hour per die, then, is 53.73 x .032 = 1.72. The number of dies required for 1102 lbs of product is $\frac{1102}{1.72}$ or 640. This data, and data for pancakes and Zwieback toast is given in Table 3.

A die large enough to produce a product food bar 1" x 2" x 1/2" would need a spacing of about 1.9 inches. If placed in a straight line, this machine would be over 100 feet long, and each die would have to be loaded and unloaded by a separate feed mechanism. To simplify the die loading and unloading and to decrease the required machine floor space, it was decided to place the dies in a circular pattern and rotate the machine so that the load-eject stations would be the same for all dies. A machine with 640 dies and the above die spacing would then be 101.3 feet in circumference, or 32.2 feet in diameter. A rotating machine of this size would still be too complex and costly. Three machines, each having 213 dies would greatly simplify the design, being only 11 feet in diameter. A concept of this machine is shown in Figure 17, with an enlarged detail of a die element shown in Figure 18.

Providing one common loading and ejecting station to serve all dies would require the machine to rotate once during a pressing cycle, which is 67 seconds. Rotational speed then is $\frac{60}{67}$ or .895 R.P.M., giving .895 x 213 = 191 bars per minute. Three machines then give 191 x 60 x 3 =34,400 bars per hour which is the required production for 1102 lbs of product per hour. One food pressing cycle (one revolution of the machine) is shown in Figure 16.

The vacuum outlet and the filler inlet are plunger type valves with the plunger extending into the sleeve flush with the inside surface to prevent plugging. The valve plunger may be solenoid actuated and switch controlled, or a spring loaded cam actuated type. The die must also contain a cartridge type heater to control the filler material temperature.

VI. CONCLUSION

Infiltration of porous foods with high caloric fillers by the vacuum release system and by the positive pressure system is feasible on a large scale production basis. Most of the equipment for handling, mixing, blending, feeding, etc. is available commercially and the equipment that would have to be designed is not so complex that it would prove economically infeasible. It is recommended that further study be given the equipment and that a pilot plant be defined for the above two systems.

FOOD AND FILLER DENSITY AND FLOW DATA

		1	2	3	4	5	6	7	8	9	10
FOOD	METHOD OF IMPREGNATION	FOOD ORIGINAL DENSITY GMS/CC	IMPREGNATED DENSITY GMS/CC	WEIGHT GAIN GMS/CC	% FOOD IN FINAL PRODUCT	% FILLER IN FINAL PRODUCT	LBS FOOD IN 1102 LBS OF PRODUCT	LBS FILLER IN 1102 LBS OF PRODUCT	FILLER INGREDIENTS	% INGREDIENTS IN TOTAL FILLER	LBS FILLER INGREDIENTS IN 1102 LBS PRODUCT
FREEZE-DRIED BEEF	VACUUM RELEASE	.44	.99	.55	44.5%	55.5%	490.0	612	STARCH	50%	306
									CCC	50%	306
FREEZE-DRIED CHICKEN	VACUUM RELEASE	.39	.89	.50	43.8%	56.2%	481.0	621	STARCH	50%	310.5
									CCC	50%	310.5
FREEZE-DRIED SHRIMP	VACUUM RELEASE	.31	1.15	.84	26.9%	73.1%	298.0	804	STARCH	50%	402
									CCC	50%	402
FREEZE-DRIED COTTAGE CHEESE	VACUUM RELEASE	1.20	1.45	.25	82.7%	17.3%	729.5	372.5	POWDERED SUGAR	16.5%	181.8
									CCC	17.3%	190.5
									PINEAPPLE FLAVORING	.014%	.15
FREEZE-DRIED* PEAS	VACUUM RELEASE	.125	.951	.826	13.1%	86.9%	144.40	957.6	STARCH	50%	478.8
									CCC	50%	478.8
FREEZE-DRIED ASPARAGUS	VACUUM RELEASE	.062	.58	.52	10.7%	89.3%	118.00	984	STARCH	50%	492
									CCC	50%	492
FREEZE-DRIED STRAWBERRIES	VACUUM RELEASE-COATED	.083	.95	.87	8.7%	91.3%	95.87	1006.22	SUGAR	41.0%	451.82
									CHOCOLATE	37.7%	415.45
									MYVEROL	12.6%	138.85
FREEZE-DRIED APPLES	VACUUM RELEASE	.14	.80	.66	17.5%	82.5%	192.85	909.15	CONF. SUGAR	40.03%	441.13
									CCC	40.03%	441.13
									LECITHIN	.20%	2.21
									STARCH	1.34%	14.74
									GRAD. SUGAR	.69%	7.37
									CINNAMON	.18%	2.04
									NUTMEG	.05%	.52

*Density values include voids between peas.

TABLE I (CONTINUED)

FOOD AND FILLER DENSITY AND FLOW DATA

		1	2	3	4	5	6	7	8	9	10
FOOD	METHOD OF IMPREGNATION	FOOD ORIGINAL DENSITY GMS/CC	IMPREGNATED DENSITY GMS/CC	WEIGHT GAIN GMS/CC	% FOOD IN FINAL PRODUCT	% FILLER IN FINAL PRODUCT	LBS FOOD IN 1102 LBS OF PRODUCT	LBS FILLER IN 1102 LBS OF PRODUCT	FILLER INGREDIENTS	% INGREDIENTS IN TOTAL FILLER	LBS FILLER INGREDIENTS IN 1102 LBS PRODUCT
PUFFED RICE	VACUUM RELEASE-COATED	.008	.43	.42	1.86%	98.1%	20.50	1081.5	SUGAR	47.0%	517.9
									CHOCOLATE	38.4%	422.6
									MYVEROL	12.8%	140.8
ZWIEBACK TOAST	PRESSURE	.22	.93	.71	23.65%	76.4%	261.00	842	PEANUT BUTTER	40%	336.8
									JELLY	40%	336.8
									MYVEROL	20%	168.4
POUND CAKE	PRESSURE	.37	.88	.51	42%	58%	462.00	638	CONF. SUGAR	32.25%	206
									CCC	12.6%	80.4
									CREAM	5.15%	32.8
									LECITHIN	.125%	.8
									CCC	49.875%	318
PANCAKE	PRESSURE	.48	.92	.44	52.2%	47.8%	576.00	527	CONF. SUGAR	32.18%	169.6
									CCC	12.57%	66.3
									CREAM	5.14%	27.1
									CCC	49.77%	262.3
									VANILLA FLAVORING	.1%	.53
									MAPLE FLAVORING	.1%	.53
									LECITHIN	.12%	.66
MACARONI	INJECTOR	.29	.47	.18	61.7%	38.3%	675.50		CHEESE	2.1%	23.1
									STARCH	.7%	7.7
									PWD. FAT	.7%	7.7
									MYVEROL	35.2%	387.9

TABLE 1 (CONCLUDED)

FOOD AND FILLER DENSITY AND FLOW DATA

	FOOD	METHOD OF IMPREGNATION	1 FOOD ORIGINAL DENSITY GMS/CC	2 IMPREGNATED DENSITY GMS/CC	3 WEIGHT GAIN GMS/CC	4 % FOOD IN FINAL PRODUCT	5 % FILLER IN FINAL PRODUCT	6 LBS FOOD IN 1102 LBS OF PRODUCT	7 LBS FILLER IN 1102 LBS OF PRODUCT	8 FILLER INGREDIENTS	9 % INGREDIENTS IN TOTAL FILLER	10 LBS FILLER INGREDIENTS IN 1102 LBS PRODUCT
BEEF STEW	RICE 50%	VACUUM RELEASE				70%	30%	385.70	165.30	CCC	15%	165.3
	BEEF 30%	VACUUM RELEASE				44.5%	55.5%	147.10	183.48	STARCH	8.325%	91.74
										CCC	8.325%	91.74
	PEAS 19%	VACUUM RELEASE				13.1%	86.9%	27.43	181.92	STARCH	8.255%	90.96
										CCC	8.255%	90.96
	ONIONS 1%	VACUUM RELEASE				66%	34%	7.27	3.75	CCC	.34%	3.75

TABLE 2

VOLUME DATA - VACUUM CHAMBER

Food	Q Flow Rate lbs/hr	D Density gms/cc	$\frac{Q453.6}{D16.39}$ Volume cu in/hr	Q_1 Filler Flow Rate lbs/hr	D_1 Filler Density gms/cc	$\frac{Q_1 453.6}{D_1 16.39}$ Filler Volume cu in/hr
Puffed Rice	42.0	.008	2,381,400	508.0	.42	33,470
Chicken	484.0	.390	34,346	621.0	.50	34,370
Beef	491.0	.440	30,880	612.0	.55	30,780
Shrimp	298.0	.310	26,600	806.0	.84	26,550
Peas	144.4	.125	32,000	957.6	.83	40,000
Asparagus	118.0	.062	52,650	990.0	.52	52,670
Strawberries	78.2	.083	26,064	460.6	1.40	9,100
Apples	243.0	.140	48,017	381.0	.66	16,000
Cottage Cheese	794.4	1.200	18,310	352.6	.25	40,000
Rice	385.7	0.790	13,500	165.3	.80	5,700
Onions	7.3	0.120	1,680	3.7	.80	128

TABLE 3

PRODUCTION DATA - POSITIVE PRESS

Food	Impregnated Density gms/cc	Impregnated Density lbs/cu in	Weight Per Bar lbs	Bars Per 1102 lbs	Lbs/ hr/die	Dies Req'd for 1102 lbs/hr.
Pound Cake	.88	.0320	.0320	34,375	1.72	640
Pancake	.92	.0330	.0330	33,000	1.77	621
Zwieback Toast	.93	.0335	.0335	32,800	1.80	611

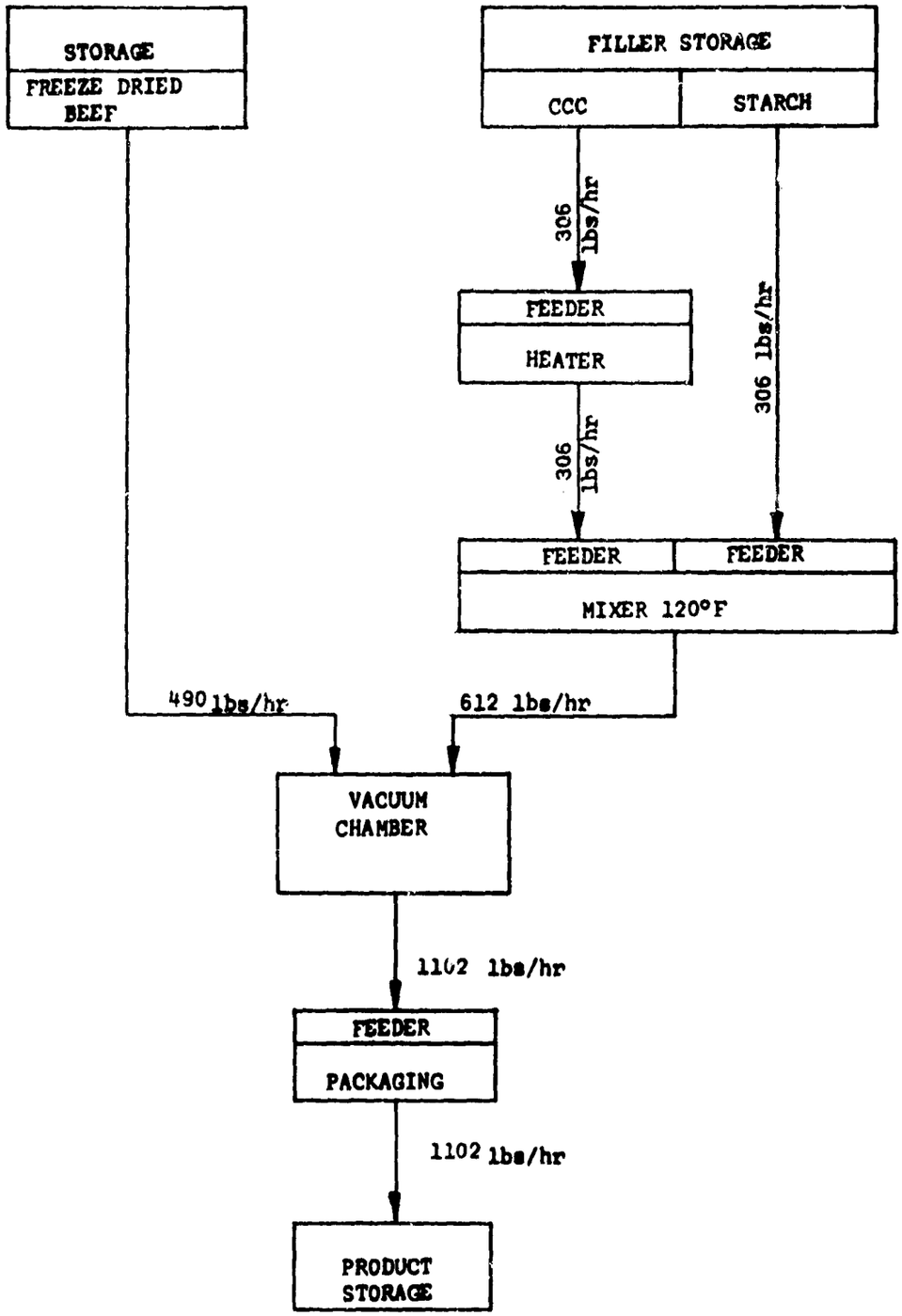


FIG. 1 PROCESS FLOW DIAGRAM
FREEZE-DRIED BEEF, 500 Kg/hr (1102 lbs/hr)

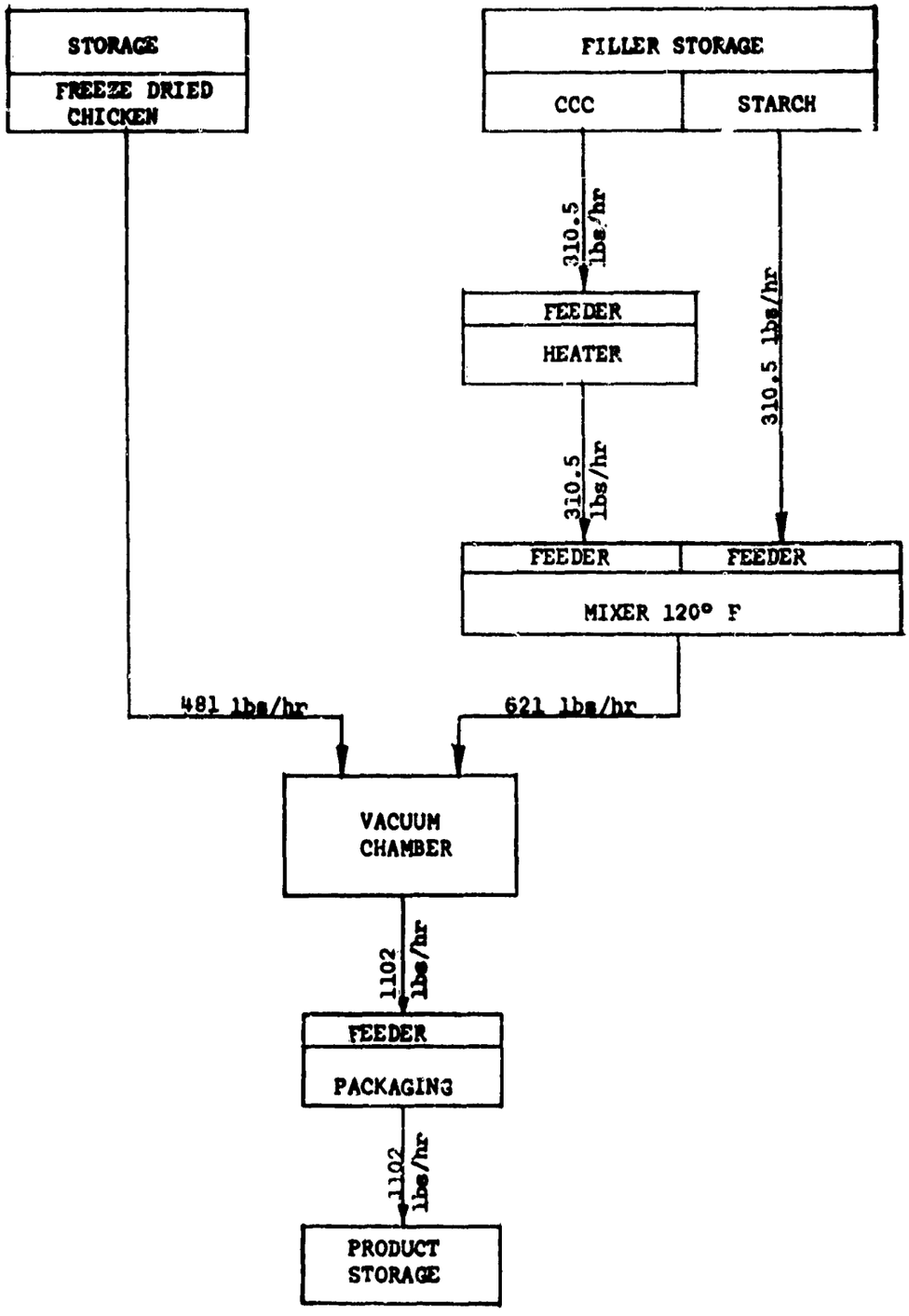


FIG. 2 PROCESS FLOW DIAGRAM
FREEZE-DRIED CHICKEN, 500 Kg/hr. (1102 lbs/hr.)

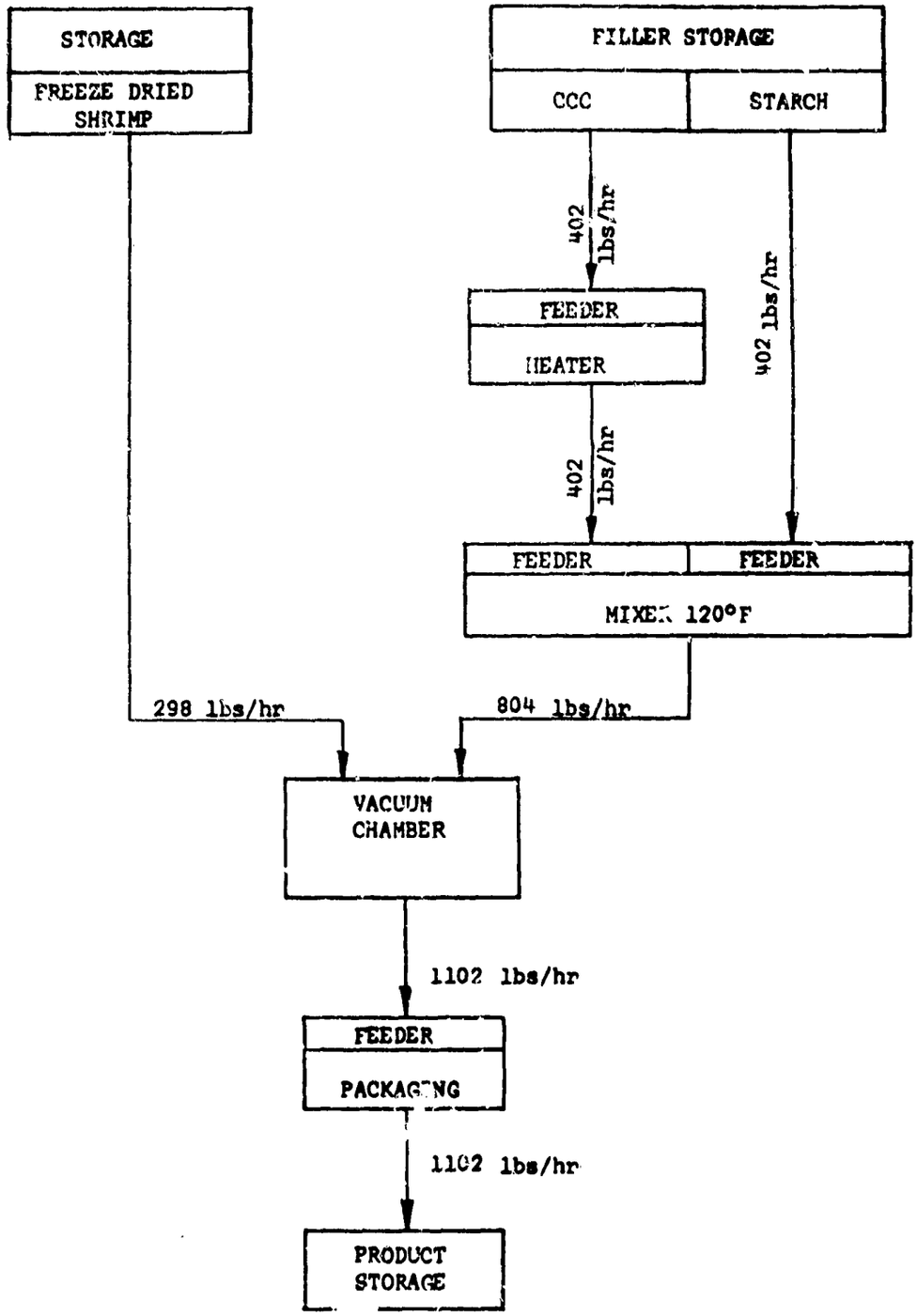


FIG. 3 PROCESS FLOW DIAGRAM
FREEZE-DRIED SHRIMP, 500 Kg/hr (1102 lbs/hr)

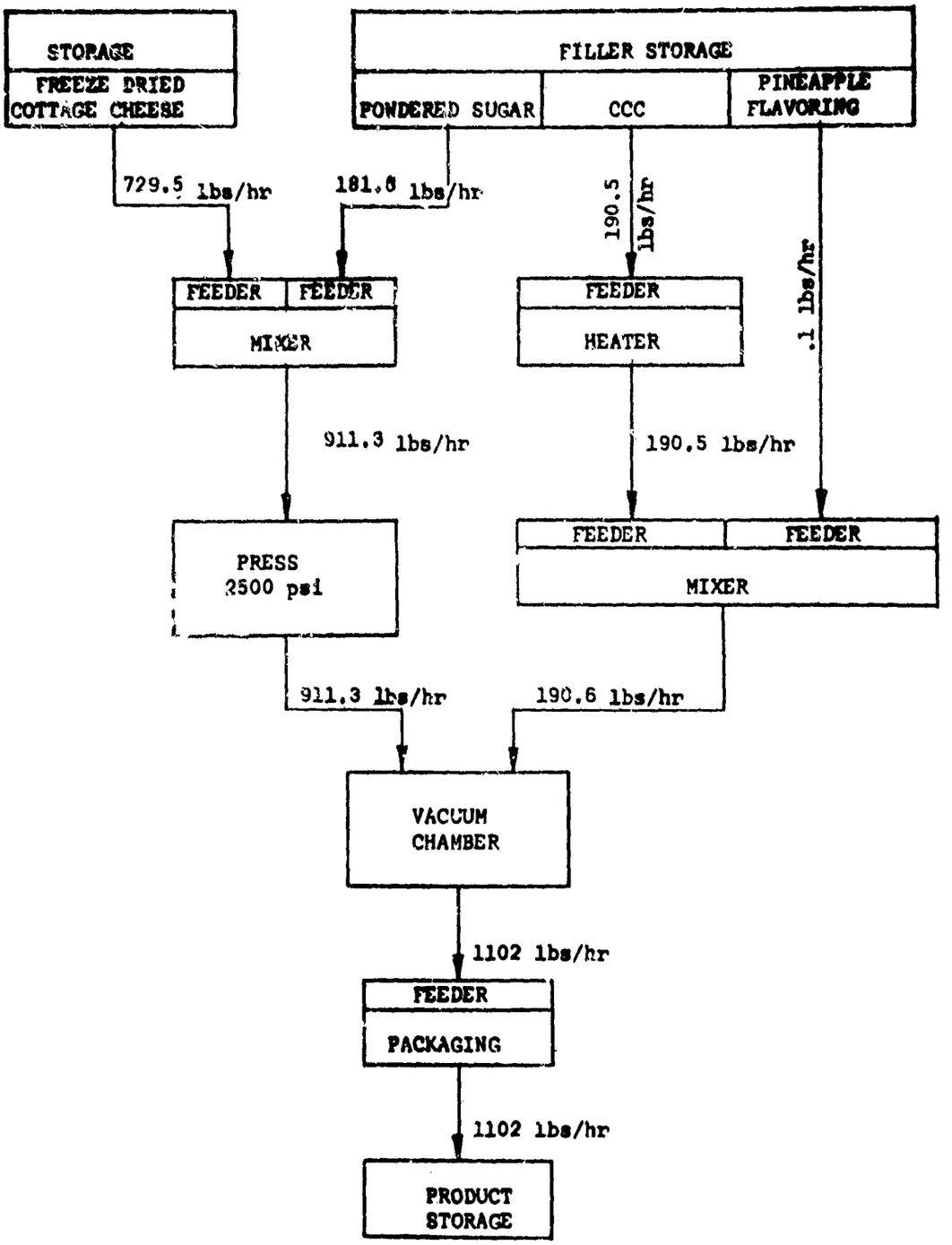


FIG. 4 PROCESS FLOW DIAGRAM
FREEZE-DRIED COTTAGE CHEESE 500 Kg/hr (1102 lbs/hr)

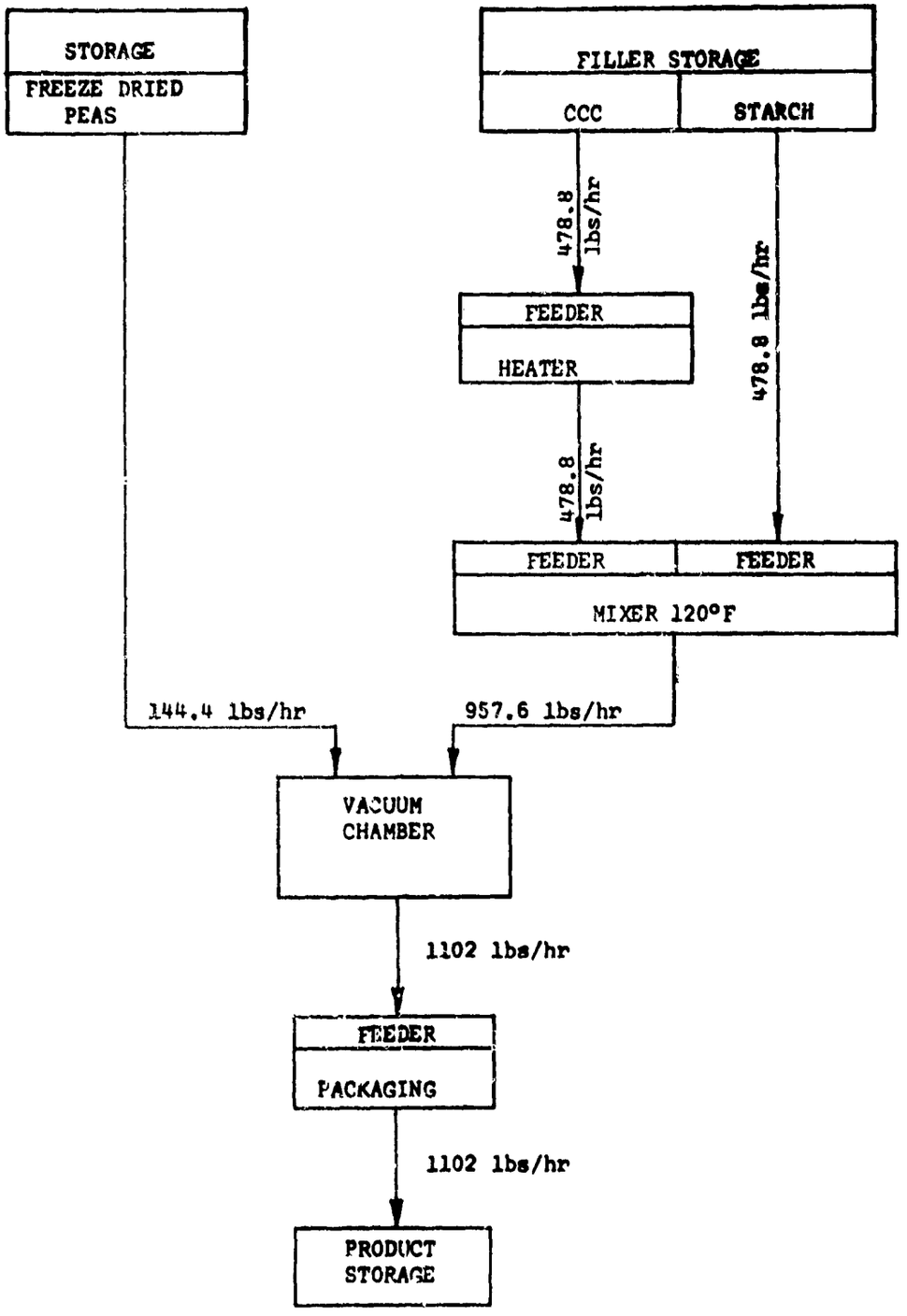


FIG. 5 PROCESS FLOW DIAGRAM
FREEZE-DRIED PEAS 500 Kg/hr (1102 lbs/hr)

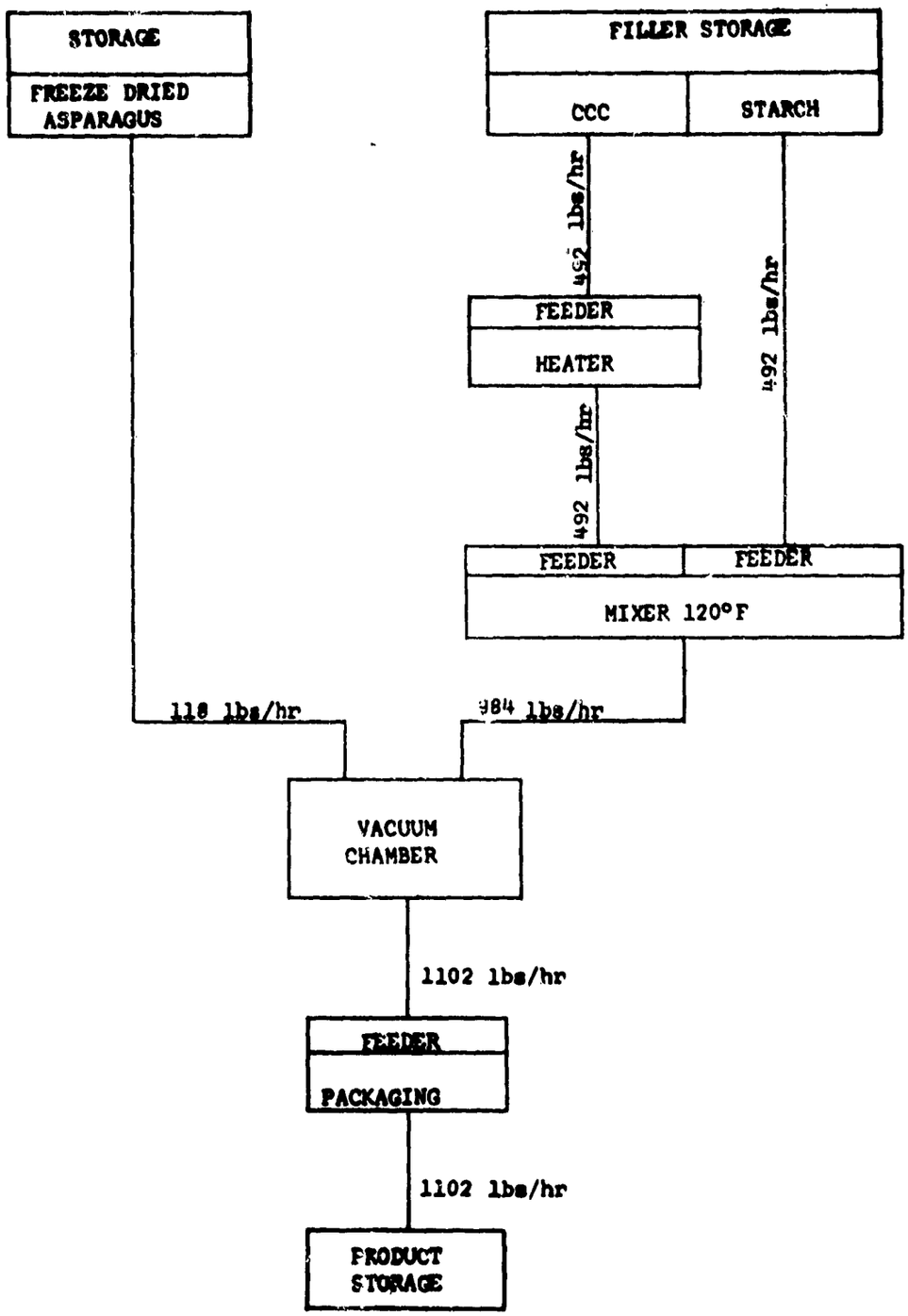


FIG. 6 PROCESS FLOW DIAGRAM
FREEZE-DRIED ASPARAGUS, 500 Kg/hr (1102 lbs/hr)

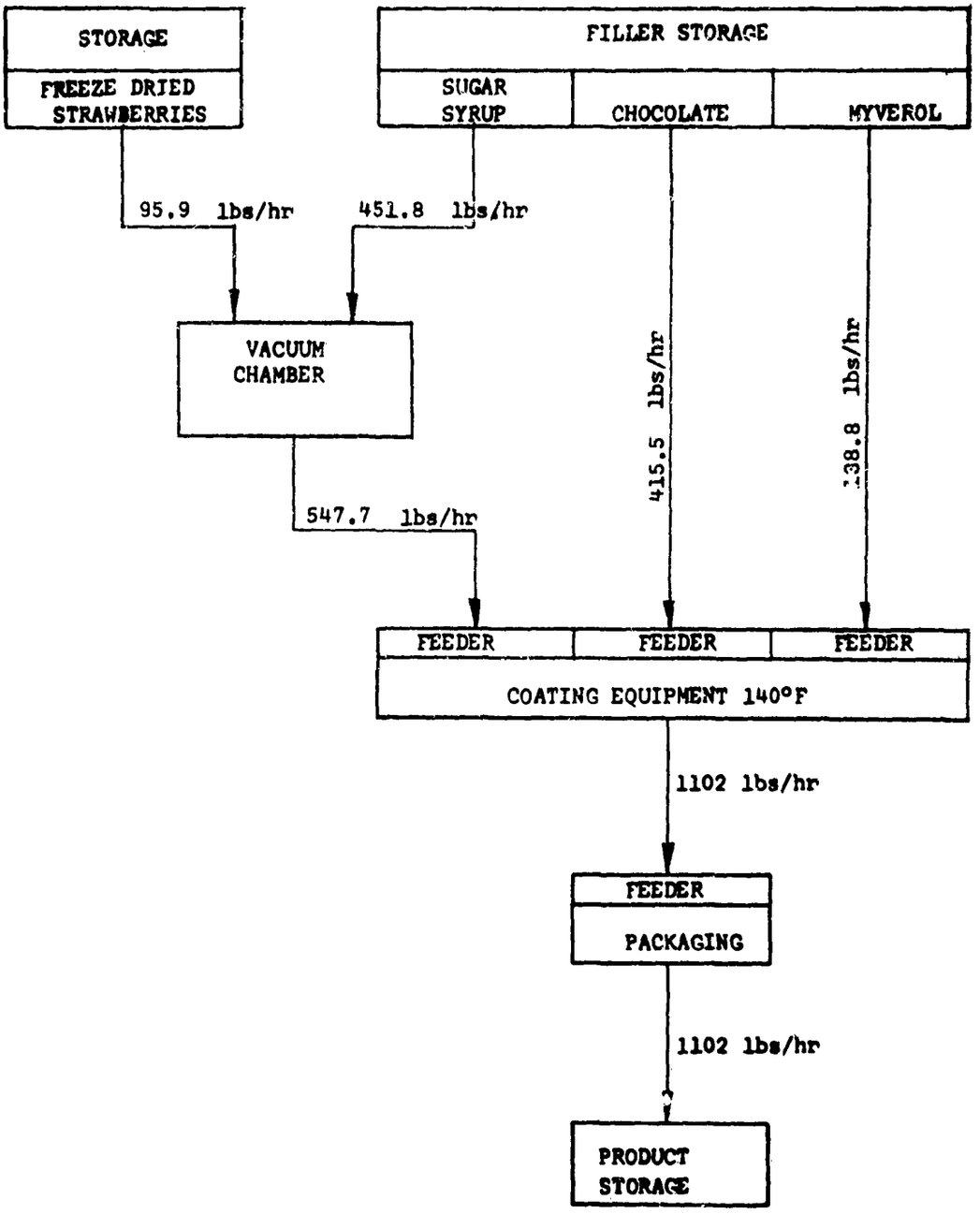


FIG. 7 PROCESS FLOW DIAGRAM
FREEZE-DRIED STRAWBERRIES 500 Kg/hr (1102 lbs/hr)

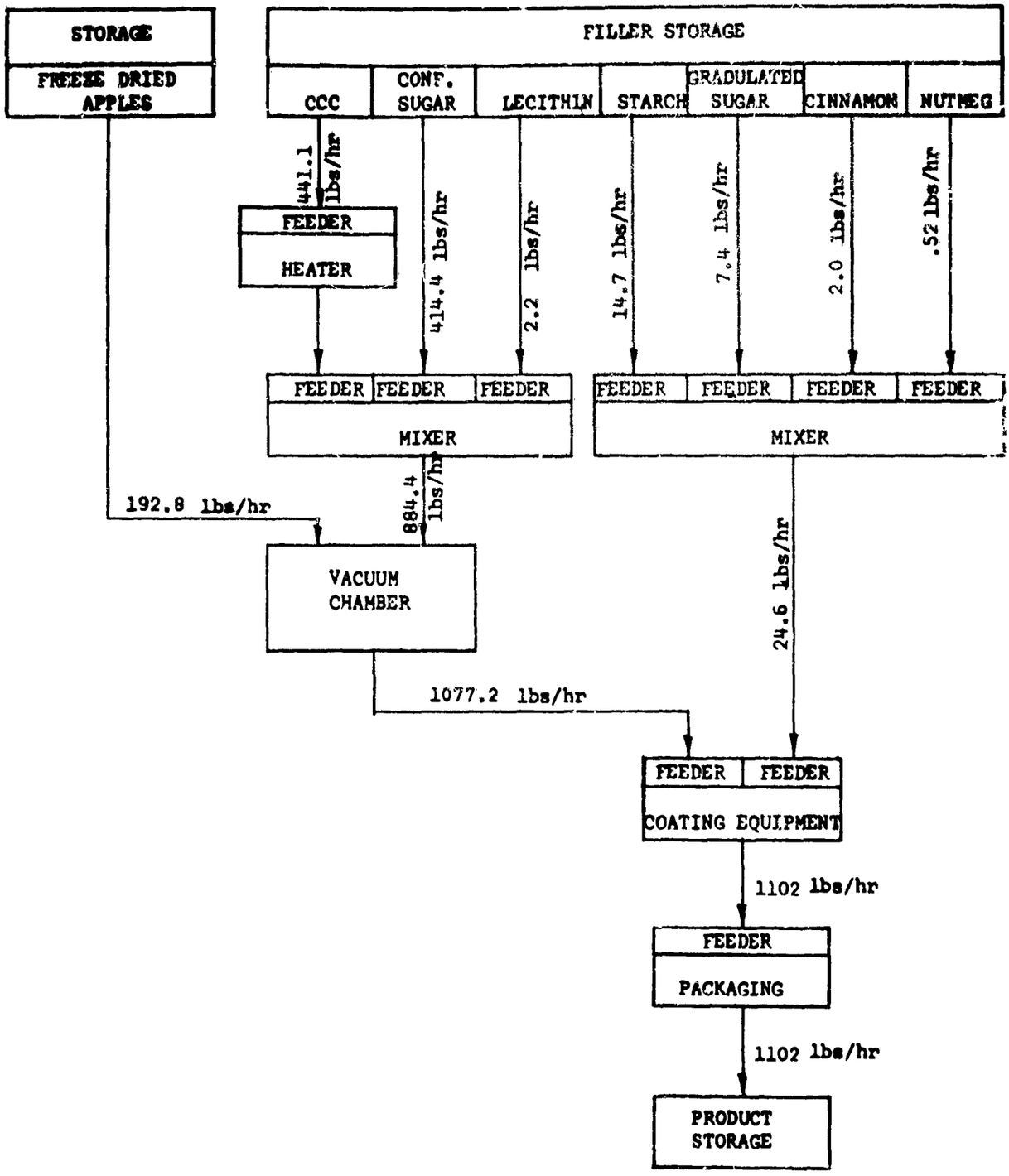


FIG. 8 PROCESS FLOW DIAGRAM
FREEZE-DRIED APPLES, 500 Kg/hr (1102 lbs/hr)

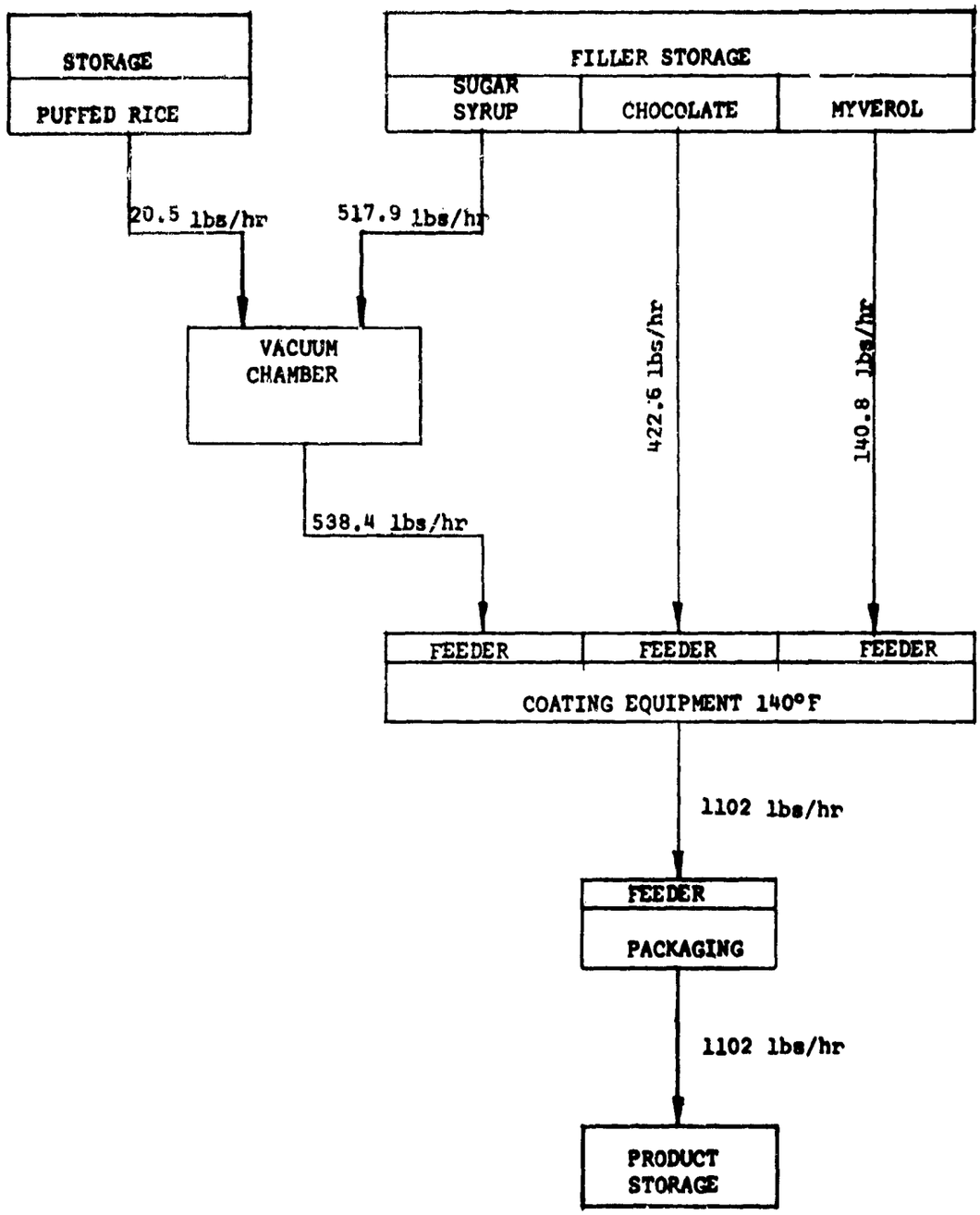


FIG. 9 PROCESS FLOW DIAGRAM
PUFFED RICE, 500 Kg/hr (1102 lbs/hr)

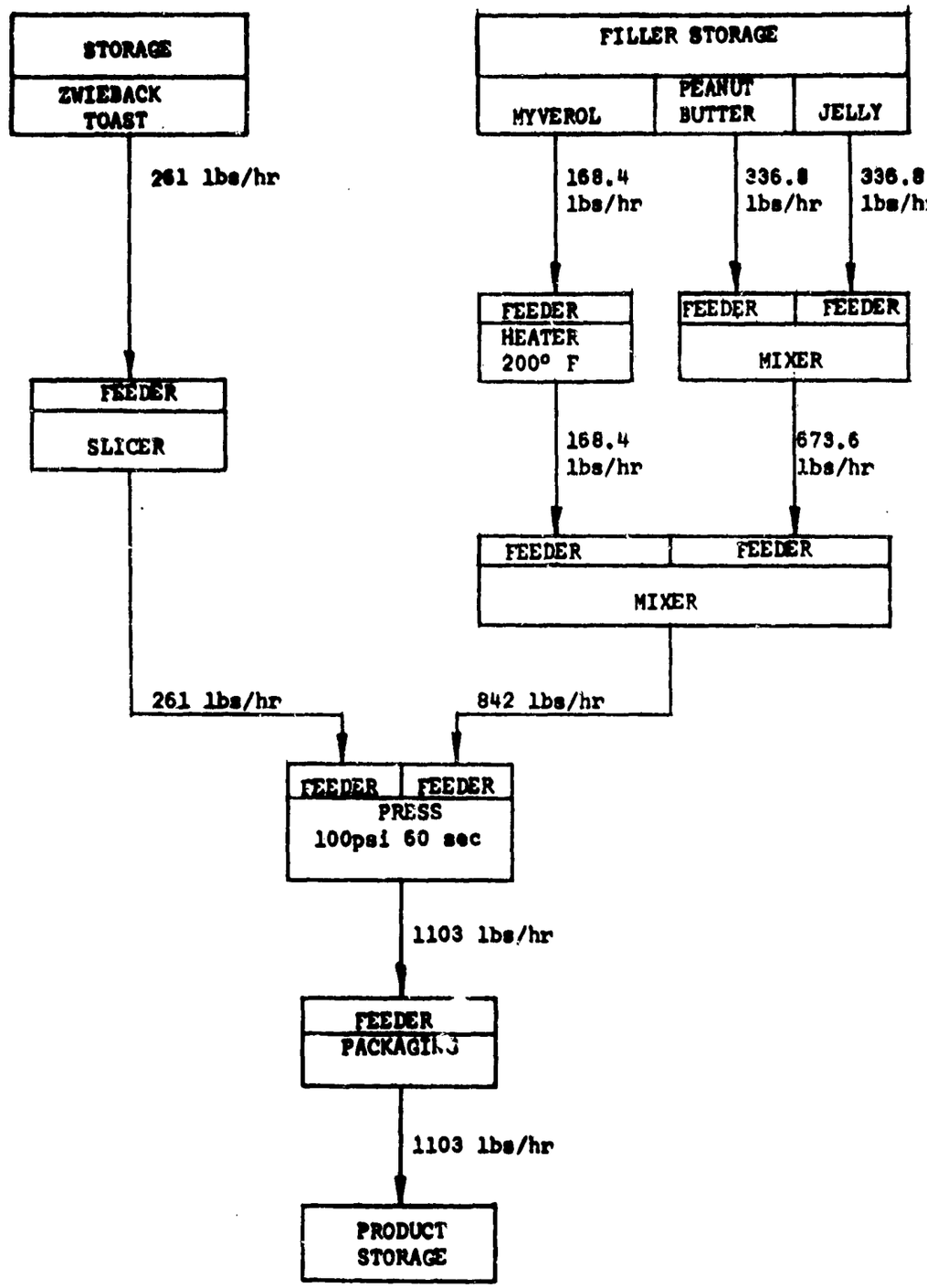


FIG. 10 PROCESS FLOW DIAGRAM
ZWIEBACK TOAST, 500 Kg/ hr (1102 lbs/hr)

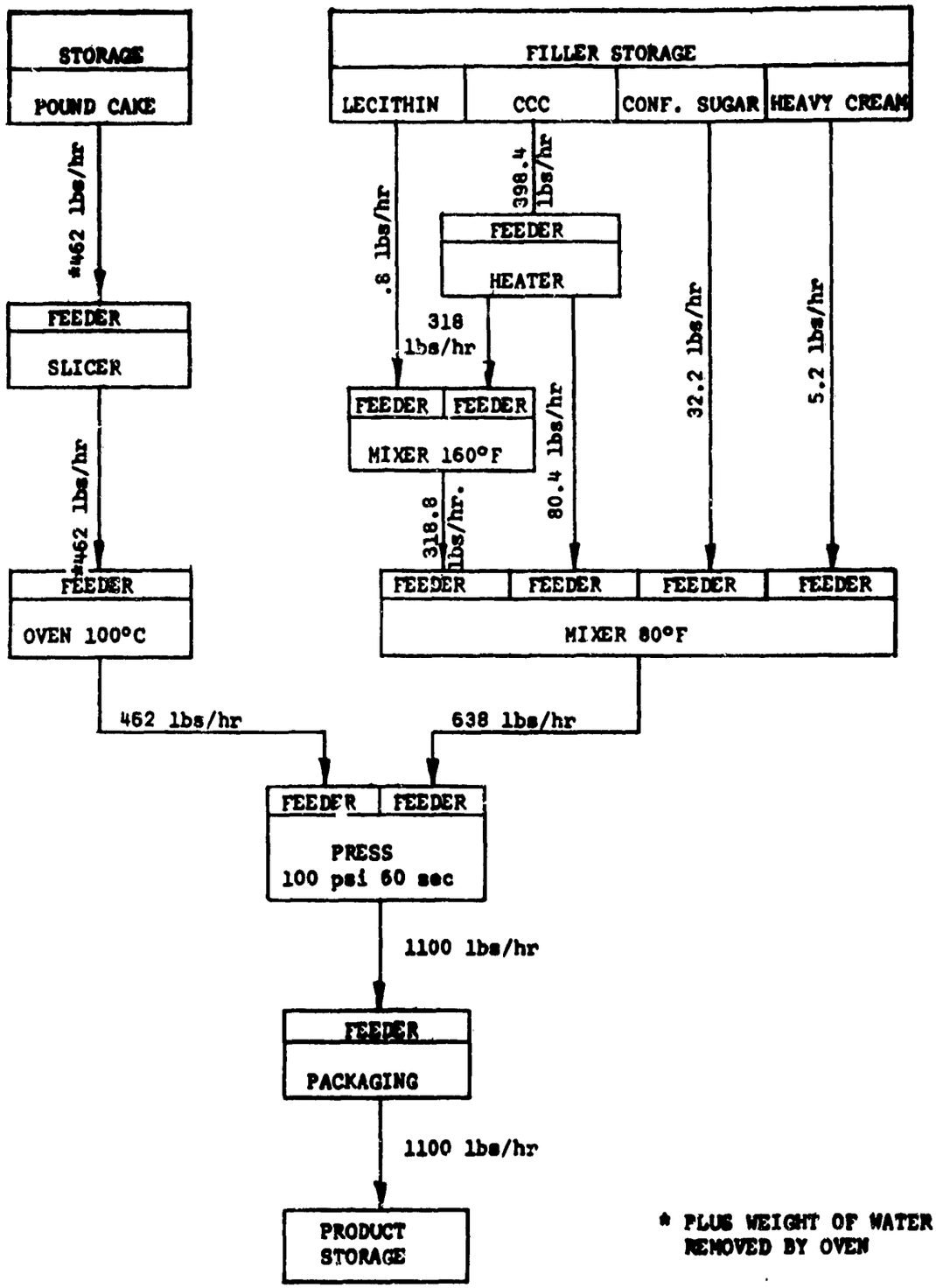


FIG.11 PROCESS FLOW DIAGRAM
POUND CAKE, 500 Kg/hr (1102 lbs/hr)

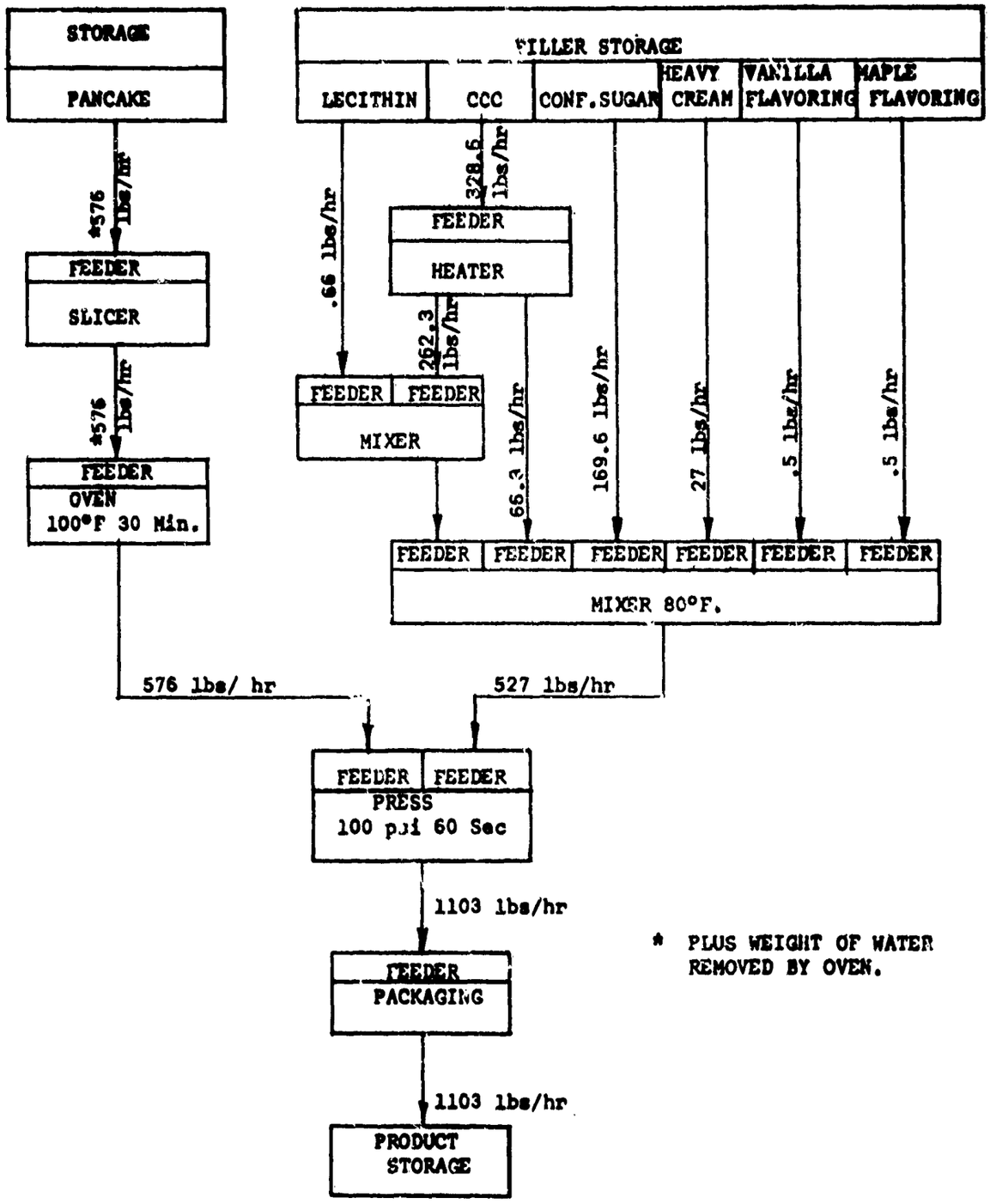


FIG. 12 PROCESS FLOW DIAGRAM
PANCAKE 500 Kgs/hr (1102 lbs/hr)

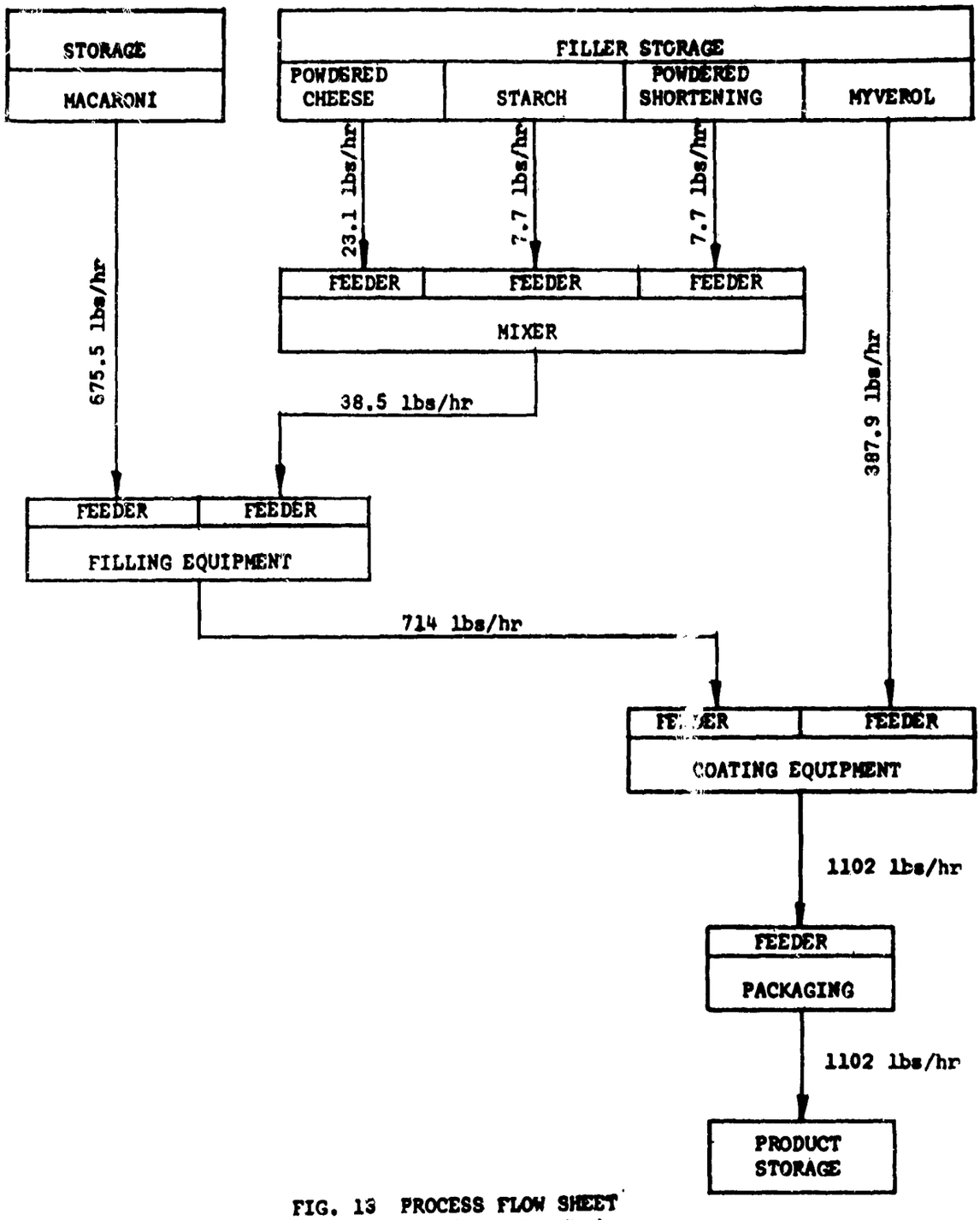


FIG. 13 PROCESS FLOW SHEET
MACARONI, 500 Kg/hr (1102 Lbs/hr)

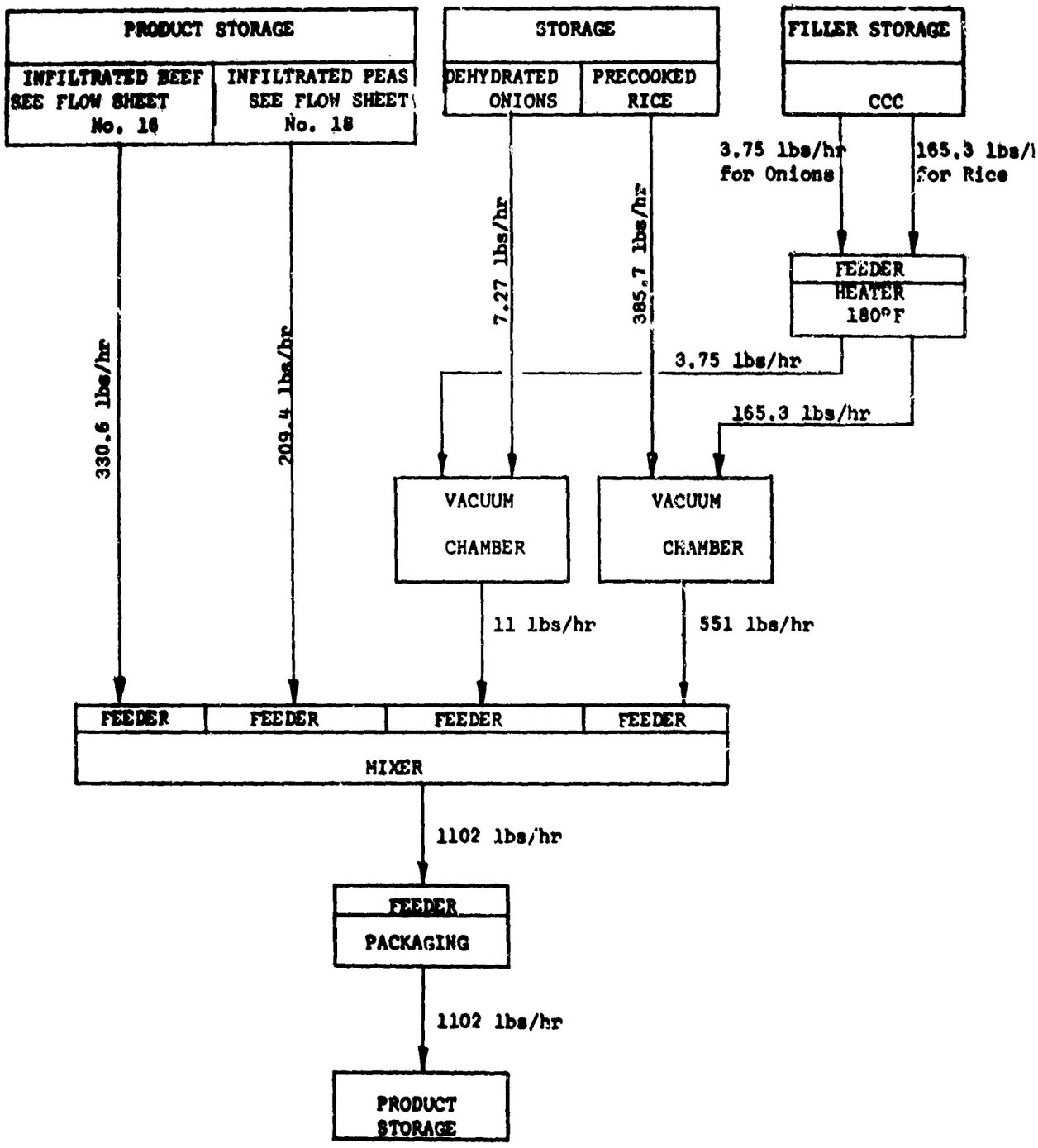


FIG. 14 PROCESS FLOW DIAGRAM
DEHYDRATED BEEF STEW 500 Kg/hr (1102 lbs/hr)

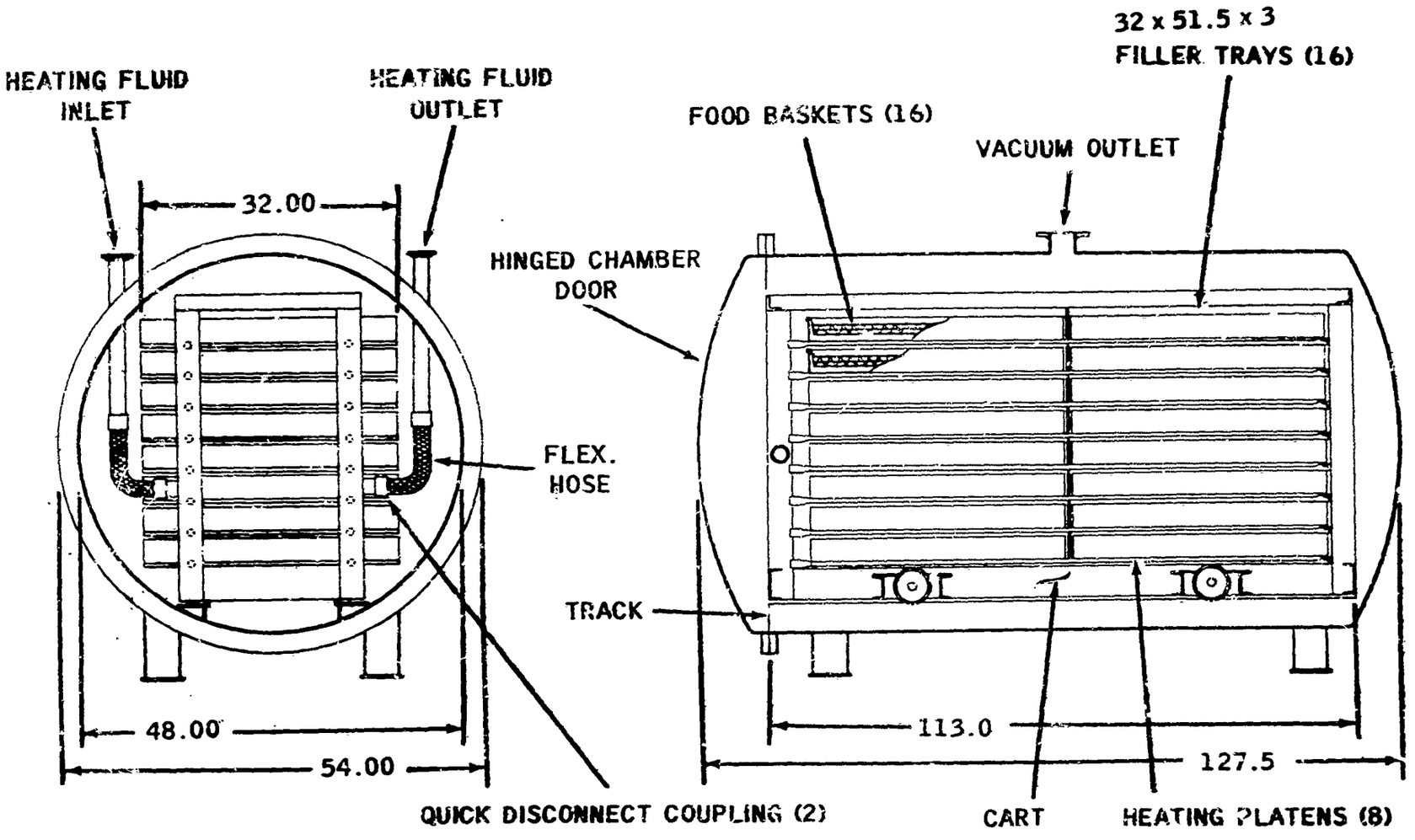


FIG. 15 — VACUUM CHAMBER & CART ASSEMBLY FOR IMPREGNATING FOOD BY THE VACUUM RELEASE SYSTEM

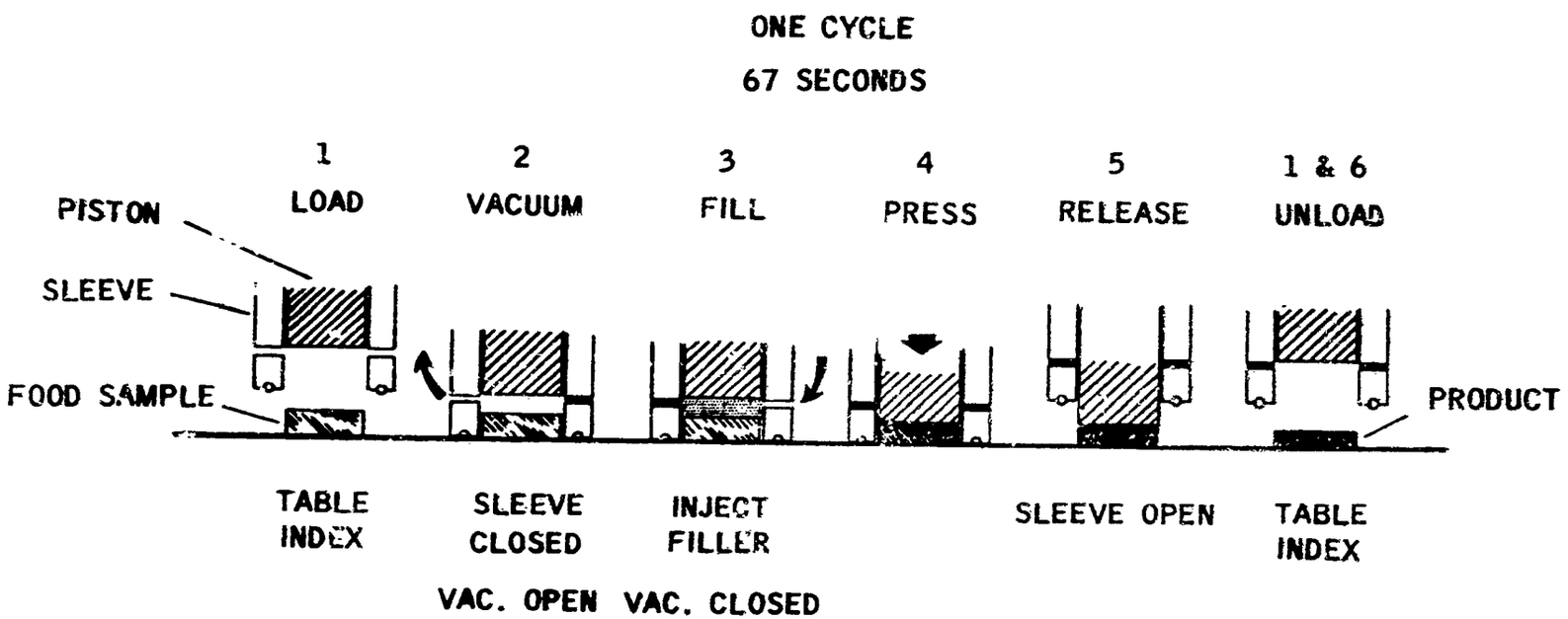


FIG. 16 POSITIVE PRESSURE FOOD IMPREGNATING

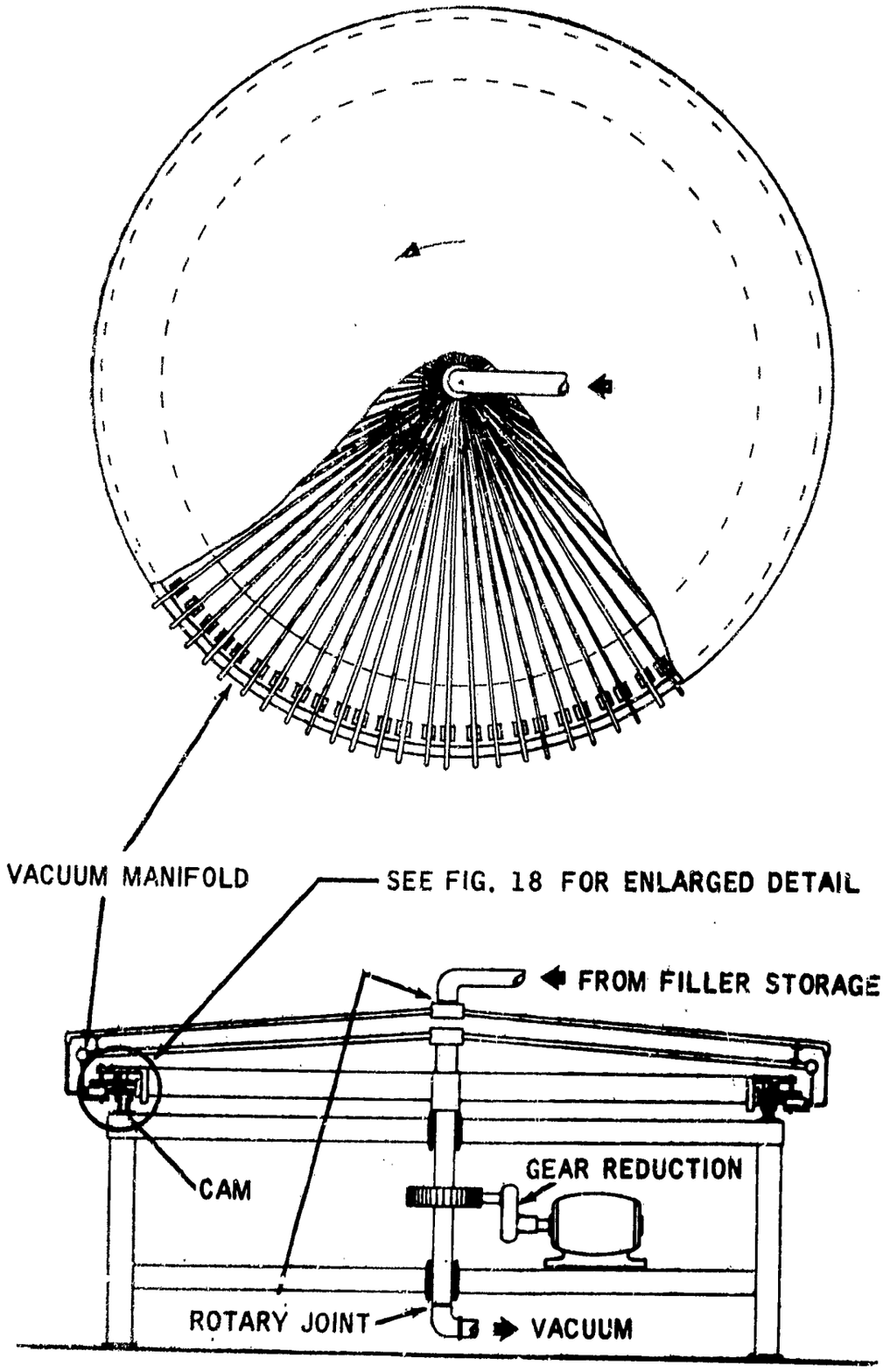
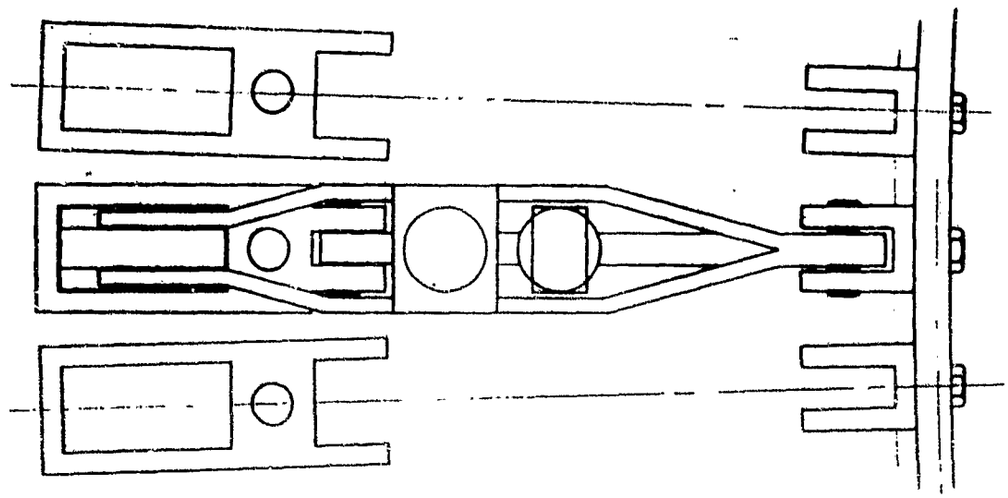


FIG. 17 POSITIVE PRESSURE FOOD IMPREGNATING



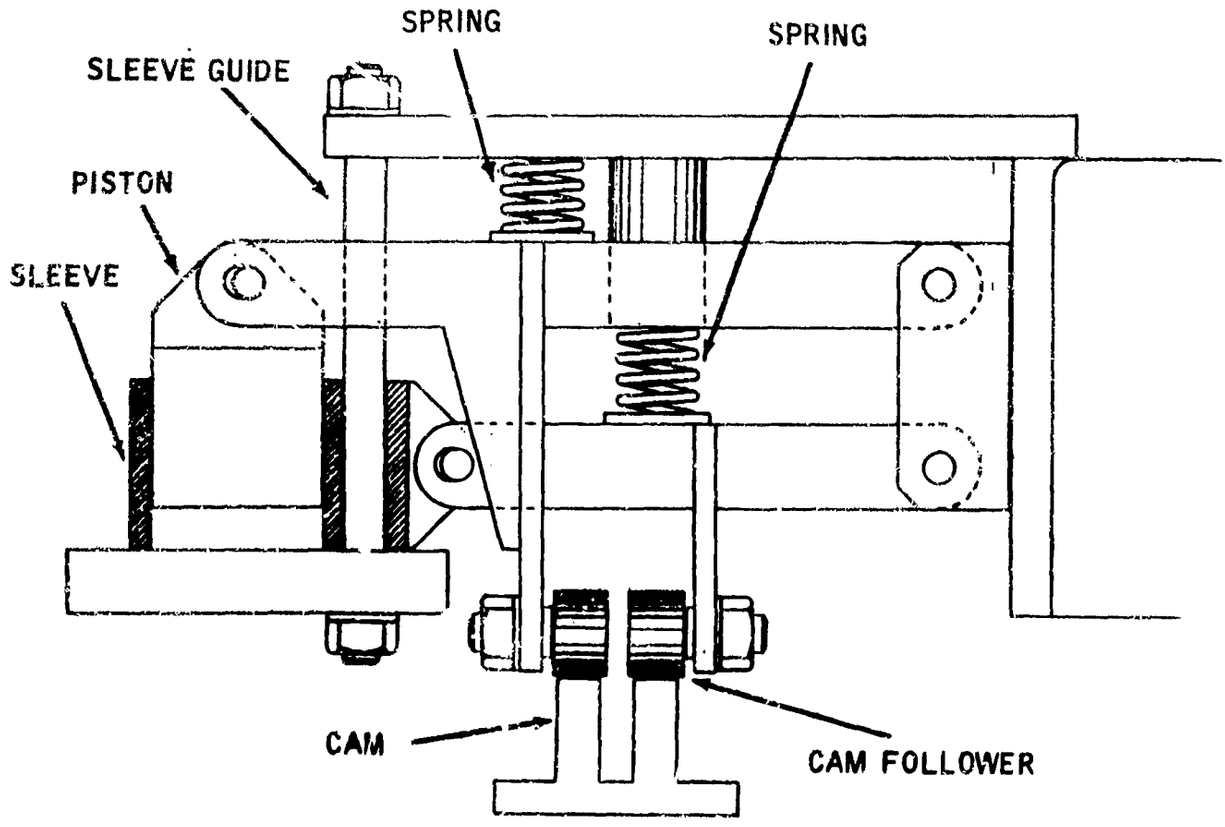


FIG. 18 PRESS SYSTEM

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ORIGINATING ACTIVITY (Corporate author)	2a REPORT SECURITY CLASSIFICATION
FMC Corporation Santa Clara, California	Unclassified
	2b GROUP

REPORT TITLE

INFILTRATION OF POROUS FOODS WITH HIGH CALORIC, NON-AQUEOUS, EDIBLE MATERIALS

DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final report 27 May 1964 - 27 May 1965

AUTHOR(S) (Last name, first name, initial)

Lampi, R.A.

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SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Animal Products Branch, Food Division U. S. Army Natick Laboratories, Natick, Massachusetts 01762

ABSTRACT

Methods, together with suitable high caloric formulations, were developed for filling the voids of representative baked items and freeze-dried meats, fruits, and vegetables. Panel tests for acceptability and relevant physical, chemical, and microbiological observations are reported for infiltered products stored for months at a maximum temperature of 38°C. Preparative experience has been extrapolated into an engineering flow diagram for large scale production of infiltered foods.

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Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Infiltration	8		10			
Fillers	1		10		9	
Food	1,2		9		9	
Freeze-dried foods	1,2		9		9	
Voids	1					
Caloric density	4,1,2		1		9	
Increasing	4		8			
High	0				0	
Storage stability					8	
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Military rations			4		4	
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